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Biology and management of the cotton mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae)

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ABSTRACT: The biology and management of cotton mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) were studied during 2008–09. *P. solenopsis* completed its development on potato sprouts quicker than on cotton plant. The total nymphal period, adult longevity, oviposition period and fecundity were more favourable on potato sprouts. Field studies showed that the insecticides, profenophos and methyl parathion were highly effective (>90% mortality) against the pest and gave the highest yield of 14.89 and 14.56 q ha^{-1}. Buprofezin and thiamethoxam were least effective and gave only 30.62–44.92% mortality, with yield of 11.56 and 11.33 q ha^{-1}. Natural products like Fish Oil Rosin Soap (FORS), combination of FORS with neem oil, neem oil alone and entomopathogenic fungus, *Verticillium lecanii* (Zimmerman), also gave effective control of *P. solenopsis*. Mineral oil @3% gave 98.41% mortality but caused phytotoxicity to the plants. The highest benefit cost ratio of 2.44 and 2.43 was observed for profenophos and methyl parathion treatments with the net income of Rs. 23,703/- and Rs. 23,162/- per ha.

KEYWORDS: cotton mealybug, biology, management

INTRODUCTION

India is the third largest global cotton producer (grown in an area of 9.37 million ha) with a production of 31.5 million bales in 2007–08 (Cotton Corporation of India, 2008). For the past two decades, the national average (526 Kg/ha) remains below the world average of 785 Kg/ha (AICCIP, 2008–2009). Of the several factors contributing to low productivity, insects are most important. Recently, outbreaks of the mealybug, *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae) have occurred, causing

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extensive yield losses, especially on Bt cotton from different States (Nagrare *et al.*, 2009). It occurred sporadically in Gujarat during 2000 and 2006 (Jhala and Bharpoda, 2008) and caused severe yield losses. Moderate level of damage was observed in parts of Maharashtra, Madhya Pradesh, Tamil Nadu and Andhra Pradesh. In a survey in Punjab, incidence of mealybug complex was noticed in all types of cotton including Bt hybrids (ICAC, 2008). Apart from the yield losses, the pest infestation has increased the cost of insecticide application by US$ 250–375 per acre in India (Nagrare *et al.*, 2009). Considering the importance of cotton crop in India and its amenability to Bt transgenic technology, it is highly essential to develop appropriate eco-friendly strategies for the management of this new pest.

MATERIALS AND METHODS

Mass culturing of *P. solenopsis* was done over potato sprouts under laboratory condition at $23 \pm 2°C$ and $69.9 \pm 5.5\%$ RH (Serrano and Laponite, 2002). The cotton seedlings required for biology studies were raised in Bio-control polyhouse in pots, adopting recommended agronomic practices. The seedlings were covered with net to prevent infestation from other mealybug species and insect pests. Thirty days old seedlings were used for rearing *P. solenopsis*.

Newly emerged first instar crawlers were released @ 25 numbers per plant with five replications. Observations were made daily on the development of crawlers which settled on the host plant. The number and the interval between moultings were observed. The exuviae were removed after each moulting. The same methodology was also used to study the lifecycle of the mealybug, on potato sprouts. The sprouts were grown as per the procedure explained earlier for mass culturing of *P. solenopsis*.

To evaluate different insecticides against *P. solenopsis*, a field trial was carried out during December–January (2008–09) in farmer's field at Puthur village near Coimbatore adopting randomized block design (RBD) consisting of 13 treatments including an untreated control and replicated thrice with plot size of 3×3 m^{2}. Two rounds of spraying were given starting from flowering stage at an interval of 14 days using knapsack hydraulic sprayer (Aspee®, Mumbai) with a spray fluid volume of 500 l ha^{1}. Five plants were randomly selected from each plot avoiding those from the margins. Pre and post treatment counts were recorded on 1, 3, 5, 7 and 14 days after first spray. Second round of spray was taken up on 15th day after first spraying. A 10 x hand magnifying lens was used for counting the mealybug population. The per cent mortality was recorded by observing the live and dead mealybugs. The dead mealybugs were differentiated based on non-movement and change of colour from white to grey and dark brown. At harvest, data on yield parameters were also recorded. The details of the treatments are mentioned in Table 2.

TABLE 1. Comparative biology of *Phenacoccus solenopsis* on cotton plant and potato sprout

Parameter	Host	
	Cotton plant	Potato sprout
I instar duration (d)	7.28 ± 0.03	5.24 ± 0.05
II instar duration (d)	9.25 ± 0.03	7.26 ± 0.04
III instar duration (d)	12.14 ± 0.04	12.10 ± 0.06
Total nymphal period (d)	28.67 ± 0.10	24.60 ± 0.15
Adult longevity (d)	11.22 ± 0.22	9.34 ± 0.05
Total life cycle (d)	39.90 ± 0.04	34.00 ± 0.3
Oviposition period (d)	8.16 ± 0.26	6.48 ± 0.22
No. of offsprings/mealybug	273.62 ± 17.52	348.40 ± 11

For durations, the values given are mean of five replications. For number of offsprings, the values given are mean of ten replications.

RESULTS

Biology of *Phenacoccus solenopsis* on cotton plant and potato sprouts

The life cycle of *P. solenopsis* was shorter on potato sprouts than on cotton plants. Except the third nymphal period, all other life stages were shorter on potato sprouts compared to cotton plants (Table 1). The duration of first instar and third instar nymphs was longer (7.28 and 9.25 d) on cotton seedlings than on potato sprouts (5.24 and 7.26 d). The life span of third instar nymph was equal on both hosts (12.14 and 12.1 d). Survival of adult female differed significantly among the hosts and it was highest on cotton plant (11.22 d) and shortest on potato sprouts (9.34 d). Similar trend was observed for oviposition period on cotton (8.16 d) and potato (6.48 d) (Table 1). The fecundity of adult female was high on potato sprouts (348.4 nymphs) when compared to cotton plant (273.62 nymphs). The total life span of *P. solenopsis* was completed in 39.9 and 34 d on cotton plant and potato, respectively. The crawlers settled mostly on the adaxial surface of the leaves in case of cotton plants and produced crinkling symptoms within 10 days after inoculation. The nymphs settled on tender shoots of potato sprouts and infested shoots and leaves dried in course of time after release.

First instar: The individuals lacked mealy wax coating, oblong in shape, light yellow in colour and highly mobile without permanent feeding site. The body had a total length and width of 12.66 ± 0.51 mm and 0.82 ± 0.42 mm, respectively. The filiform antenna has 8 to 9 segments with a length of 1.53 ± 0.07 mm. The meta-thoracic legs were the longest and measured of 4.94 ± 0.12 mm while the pro-thoracic and meso-thoracic legs measured 4.10 ± 0.08 mm and 4.39 ± 0.20 mm, respectively.

Second instar: The crawlers settled mostly on the undersurface of the tender leaves in large numbers. This stage was devoid of mealy coating, and yellow in colour. The total body had a length and width of 13.62±0.65 mm and 8.09±0.41 mm, respectively. The antenna is 8 segmented with a length of 1.46 ± 0.07 mm. The pro-thoracic,

TABLE 2. Field efficacy of insecticides against *Phenacoccus solenopsis* and yield of cotton

Treatment	Concentration (%)	Pre-treatment Count (No.)	Percent mortality 14 DAT	Percent mortality 28 DAT	Yield (Q ha^{-1})	Gross income (Rs.)	Cost of cultivation + cost of protection (Rs.)	Net income (Rs.)	Benefit cost ratio
FORS (Fish Oil Rosin Soap)	2.5	44.67	73.16 $(58.83)^{de}$	83.29 $(65.90)^{c}$	13.56	36,612	17,625	18,987	2.08
FORS + neem oil	2.5 + 1	44.67	74.80 $(59.88)^{d}$	84.23 $(66.66)^{c}$	13.67	36,909	18,125	18,784	2.04
Neem oil	2	40.67	49.06 $(44.46)^{h}$	55.92 $(48.41)^{f}$	12.11	32,697	17,250	15,447	1.90
Mineral oil	3	46.67	81.42 $(64.48)^{c}$	92.51 $(74.30)^{b}$	11.56	31,212	18,000	13,212	1.73
Verticillium lecani	10^{8} cfu ml^{-1}	45.33	70.10 $(56.88)^{e}$	75.61 $(60.42)^{d}$	13.11	35,397	15,900	19,497	2.23
Profenophos 50 Ec	1.25	41.33	92.72 $(74.56)^{a}$	97.67 $(82.60)^{a}$	14.89	40,203	16,500	23,703	2.44
Thiamethoxam 20 WG	0.08	45.67	30.62 $(33.59)^{j}$	30.98 $(33.82)^{g}$	11.33	30,591	18,150	12,441	1.69
Buprofezin 25 SC	0.18	47.00	36.63 $(37.24)^{i}$	35.52 $(36.57)^{g}$	11.56	31,212	17,046	14,166	1.83
Spirotetramat 240 SC	2.83	42.33	59.17 $(50.29)^{fg}$	67.48 $(55.25)^{e}$	12.89	34,803	16,870	17,933	2.06
Spirotetramat + Imidacloprid 480 SC	3.45	45.33	54.27 $(47.45)^{g}$	62.96 $(52.52)^{ef}$	12.67	34,209	16,686	17,523	2.05
Methyl parathion 50 EC	1	44.00	89.56 $(71.41)^{b}$	97.33 $(81.91)^{a}$	14.56	39,312	16,150	23,162	2.43
Methyl demeton 25 EC	0.5	47.33	61.12 $(51.43)^{f}$	76.65 $(61.11)^{d}$	13.33	35,991	16,350	19,641	2.20
Control (Untreated check)	–	44.00	0.00 $(1.28)^{k}$	0.00 $(1.28)^{h}$	10.11	27,297	15,250	12,047	–
CD value (0.05)		–	0.7873	0.5112					

DAT, Days after treatment. Figures in parantheses are arcsine transformed values. Means followed by same letter(s) in a column are not significantly different by DMRT ($P = 0.05$).

meso-thoracic and meta-thoracic legs measured 4.02 ± 0.08 mm, 4.12 ± 0.11 mm and 4.45 ± 0.10 mm, respectively.

Third instar: The crawlers has white mealy wax coating all over the body, oval in shape, dark yellow in colour and aggregated largely on stems. The body measured 13.87 ± 0.79 mm in length and 9.10 ± 0.44 mm in width. The filiform 8-segmented antenna has a length of 1.25 ± 0.07 mm. The pro-thoracic, meso-thoracic and meta-thoracic legs had a length of 4.02 ± 0.09 mm, 4.33 ± 0.10 mm and 4.49 ± 0.12 mm, respectively.

Field efficacy of insecticides

Among the treatments, profenophos and methyl parathion were found to be highly effective in reducing the mealybug population (>92% mortality) in both the rounds of spray (Table 2). Both the treatments were on par in their efficacy. Mineral oil recorded second highest percentage of mortality of 81.42 and 92.51 per cent at 14 and 28 days after the treatment but was phytotoxic. Chemicals like, methyl demeton, spirotetramat, combination of spirotetramat and imidacloprid were statistically significant in their effects on the mortality of mealybugs over untreated check. Buprofezin and thiamethoxam were least effective and recorded only 36.63, 35.52 and 30.62, 30.98 per cent mortality, respectively, at 14 and 28 days after the treatment.

Fish Oil Rosin Soap (FORS) and combination of FORS with neem oil registered 73.16, 83.29 to 74.80, 84.23 per cent mortality of mealybugs and these treatments were on par with each other in both the spray. Neem oil recorded 49.06 and 55.92 per cent mortality of the mealybugs. The treatment with mineral oil @ 3 per cent caused phytotoxicity of leaves in all the plots and the plant started drying in course of time which reduced the yield of cotton to an extent of 1.04 kg/plot.

The efficacy of the fungus, *Verticillium lecanii* (Zimmerman) was found increasing constantly from third day after first spray and recorded 70.10 and 75.61 per cent mortality at 14 days after first and second spray respectively. Synthetic chemicals inflicted higher percentage of mortality of mealybugs.

Yield and economics

The yield of cotton was recorded in various treatments in the field experiments and benefit cost ratio was worked out. Significant difference was observed on the yield of cotton between the control plot and other treated plots. Profenophos and methyl parathion treated plots recorded the highest yield of 14.89 and 14.56 q ha^{-1}. The highest benefit cost ratio of 2.44 and 2.43 was observed for the same treatments with a net income of Rs. 23,703/- and Rs. 23,162/-. This was followed by methyl demeton, *Verticillium lecani*, FORS (Fish Soap), combination of FORS and spirotetramat and combination of spirotetramat + imidacloprid neem oil, with a net income of Rs. 19,641, 19,497, 18,987, 18,784, 17,933, 17,523 and 15,447/- over the control (Rs. 12,047/-). The treatment with neem oil, buperofezin, mineral oil and thiamethoxam recorded little increase in yield ranging from 11.33 to 12.11 q ha^{-1} as compared to control which recorded yield of 10.11 q ha^{-1} and Rs. 12,047 (Table 2).

DISCUSSION

The development of *P. solenopsis* was completed quicker on potato sprouts compared with cotton. The duration of all life stages except the third nymphal period was shorter on potato sprouts and the fecundity was also high when compared to cotton plant. A wingless female undergoes three nymphal instars and gave birth to live young by ovoviviparity. The present findings are in agreement with Hodgson *et al.* (2008) and Akintola and Ande (2008).

Among the different insecticides tested in the field, profenophos and methyl parathion were found to be highly effective against cotton mealybugs which caused >92 per cent mortality within 72 h after treatment which is in agreement with Saeed *et al.* (2007) who reported that recommended application of profenophos, methomyl and chlorpyriphos provided the best control of cotton mealybug, *P. gossypiphilous*. In the present study, FORS and combination of FORS with neem oil resulted in 73.16 to 84.23 per cent mortality of mealybugs and significantly on par in their effects and neem oil caused 49.06 to 55.92 per cent mortality. This is supported by Natarajan *et al.* (1991) who found that FORS 2%, neem oil 0.5%, and mineral oil 2% effectively suppressed the sap feeding insects of cotton when compared to synthetic insecticides. The efficacy of entomopathogenic fungus, *Verticillium lecani* was found increasing constantly which caused mortality up to 75.61 per cent. This is in conformity with the results of Kulkarni *et al.* (2003) who observed that *V. lecanii* at 4 g l^{-1} of water was the optimum for the management of mealybugs on pomegranate. The present study confirmed that potato sprouts is the most suitable host crop for mass production of cotton mealybug under laboratory conditions. An integration of chemical, biological and mechanical control is essential for long term management of mealybugs. A regular monitoring of mealybug dispersal must be carried out for the application of biocontrol agents in integration with insecticide application to achieve the maximum efficiency of natural control agents. Crawler is the most susceptible stage at which coccids can be easily controlled. Hence, timing of insecticide sprays has to coincide with the crawler stage using less persistent chemicals.

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Biology and feeding potential of three *Micromus* species (Neuroptera: Hemerobiidae) on sorghum aphid, *Melanaphis sacchari* (Zehntner)

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ABSTRACT: Biology of three *Micromus* species *viz.*, *Micromus australis* Hagen, *M. igorotus* Banks and *M. timidus* Hagen on sorghum aphid, *Melanaphis sacchari* (Zehntner) and their host destroying potential were studied. *M. timidus* had the highest reproductive potential, followed by *M. australis* and *M. igorotus*. The host destroying potential was the highest for *M. igorotus*, followed by *M. australis* and *M. timidus*.

KEYWORDS: *Micromus australis*, *M. igorotus*, *M. timidus*, *Melanaphis sacchari*

INTRODUCTION

Brown lacewings (Neuroptera: Hemerobiidae) feed on small soft-bodied arthropods, such as aphids, scale insects, and spider mites (New, 1975) and have been used in biocontrol of these pests (Eilenberg *et al.*, 2001). *Micromus timidus* Hagen was introduced from Australia to the Hawaiian Islands in 1919 for control of aphids, particularly on sugarcane and corn (Williams, 1927). *Hemerobius nitidulus* Fabricius and *H. stigma* Stephens were introduced from Europe to Canada as biological control agents against the balsam woolly aphid, *Adelges piceae* (Ratzeburg), during 1930s (Smith and Coppel, 1957). However, neither species was recovered from field (Garland, 1978), possibly because they did not adapt to the climate of Canada. Among the Hemerobiidae, *Micromus* and *Hemerobius* were reported promising as biological control agents against aphids, because of their wide range of prey and habitat (New, 1988).

Micromus australis Hagen, *M. igorotus* Banks and *M. timidus* are the species recorded in India. *M. australis* was originally described from Sri Lanka and it has been

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reported from India on sorghum and cotton ecosystem (Vidya *et al.*, 2008). The species is restricted to the Indian subcontinent. *Micromus igorotus*, described for the first time by Banks in 1920 was redescribed and illustrated by Monserrat (1993). This species was originally described from Philippines, and has since been reported from China, Indonesia, Malaysia, Taiwan and Thailand. In India it was reported for the first time as predator of sugarcane woolly aphid, *Ceratovacuna lanigera* Zehntner (Lingappa *et al.*, 2004). The species is wide spread in oriental region. *M. timidus* is restricted to the Indian subcontinent. A comparative evaluation of the above three species available in India with respect to development, adult longevity, fecundity and feeding potential was carried out and the results are reported here. The study was carried out at Dharwad during October 2004 to February 2005.

MATERIALS AND METHODS

The three species of *Micromus* were reared in plastic cages on sorghum aphid, *Melanaphis sacchari* (Zehntner). Cotton thread strings/cotton screen was used as oviposition substrate. Eggs laid on the substratum were collected every 24 h and placed individually in glass vials along with the prey, closed with cotton plugs and observed daily to record the development. Larvae and adults were individually placed in separate glass vials with known numbers of *M. sacchari* and were observed at 24h interval to assess the number of aphids preyed by predator. The aphids were replaced daily. Conspecific pair of newly emerged adults were placed in plastic containers with abundant *M. sacchari* on a leaf of *Sorghum bicolor* (L.) Moench and oviposition substrates. The number of eggs laid by adult predator was recorded at 24 h interval. The aphids were replaced daily.

RESULTS AND DISCUSSION

Data are presented in Tables 1 and 2.

Development traits

Incubation period of the three species did not show significant variation. Total larval periods of *M. timidus* and *M. australis* were on par and significantly lower than those of *M. igorotus*. Pupal period was least in *M. timidus*, highest in *M. igorotus* and in between in *M. australis*. The same ranking was seen in egg to adult and egg to egg develpoment periods. These results, in part, are in conformity with developmental periods reported earlier for *M. igorotus* (Anon., 2006; Kulkarni *et al.*, 2006) and *M. timidus* (Patnaik *et al.*, 1977; Raychaudhuri *et al.*, 1981; Radhakrishnan and Muraleedharan, 1989). Observations of Raychaudhuri *et al.* (1981) and Radhakrishnan and Muraleedharan (1989) differed in respect of incubation period.

Reproductive traits

Pre-oviposition period was least in *M. timidus*, highest in *M. igorotus* and in between in *M. australis*. Oviposition period of *M. igorotus* and *M. australis* were on par while

TABLE 1. Biology of three species of *Micromus* on *Melanaphis sacchari*

Developmental period (d)	*M. australis*	*M. igorotus*	*M. timidus*	C.D. ($P = 0.05$)
Egg	3.30 ± 0.48^{a}	3.32 ± 0.48^{a}	3.19 ± 0.40^{a}	0.18
I Instar larva	2.00 ± 0.00	2.20 ± 0.41	2.00 ± 0.00	
II Instar larva	1.35 ± 0.49	2.12 ± 0.73	1.06 ± 0.25	
III Instar larva	1.76 ± 0.44	1.96 ± 0.45	1.81 ± 0.40	
Total larval period	5.12 ± 0.49^{a}	6.28 ± 1.14^{b}	4.88 ± 0.50^{a}	0.34
Pupa	8.18 ± 0.39^{b}	9.04 ± 1.02^{c}	6.88 ± 0.34^{a}	0.52
Egg to Adult	16.62 ± 1.36^{b}	18.64 ± 2.64^{c}	14.87 ± 1.24^{a}	1.01
Egg to Egg	20.52 ± 2.24^{b}	23.08 ± 3.15^{c}	18.00 ± 1.58^{a}	0.84
Other traits				
Adult longevity, Male (d)	40.10 ± 12.0^{a}	34.50 ± 13.67^{b}	28.70 ± 14.60^{c}	4.61
Adult longevity, Female(d)	43.40 ± 13.47^{a}	44.70 ± 9.94^{a}	29.40 ± 13.07^{b}	3.98
Adult longevity, mean (♂ & ♀) (d)	41.75 ± 11.36^{a}	39.60 ± 12.76^{a}	29.05 ± 13.49^{b}	4.34
Pre-oviposition period (d)	3.90 ± 0.88^{b}	4.44 ± 0.51^{c}	3.13 ± 0.34^{a}	0.23
Oviposition period (d)	35.60 ± 11.74^{a}	36.60 ± 10.09^{a}	25.20 ± 12.49^{b}	4.81
Post-oviposition period (d)	3.60 ± 4.20^{a}	3.70 ± 2.06^{a}	1.00 ± 1.15^{b}	0.20
Fecundity (No.)	818.90 ± 33.81^{b}	673.90 ± 217.47^{c}	907.50 ± 342.15^{a}	87.11

Figures followed by the same letter in a column are not significantly different ($P = 0.05$) by DMRT.

TABLE 2. Feeding potential of three *Micromus* species on *Melanaphis sacchari*

Stage	*M. australis*	*M. igorotus*	*M. timidus*	C.D. ($P = 0.05$)
Larva				
Total				
I	58.82 ± 9.68	77.64 ± 15.62	49.81 ± 9.95	
II	67.47 ± 24.56	108.80 ± 31.34	57.69 ± 19.48	
III	96.18 ± 20.15	143.68 ± 30.06	128.25 ± 25.85	
	213.18 ± 21.95^{b}	330.12 ± 32.39^{a}	235.75 ± 33.24^{b}	42.65
Per day				
I	29.41 ± 4.84	36.04 ± 8.30	24.91 ± 4.98	
II	50.18 ± 6.78	53.72 ± 13.20	54.42 ± 8.12	
III	56.26 ± 10.20	76.35 ± 23.06	70.86 ± 11.19	
	41.82 ± 4.18	53.71 ± 8.06	50.06 ± 4.85	
Adult				
Total	585.24 ± 120.49^{b}	688.86 ± 177.40^{a}	303.58 ± 101.98^{c}	37.91
Per day	14.02 ± 9.41	17.51 ± 0.77	10.45 ± 6.67	
Larva + Adult				
Total	798.42 ± 65.31^{b}	1018.98 ± 209.79^{a}	539.33 ± 62.61^{c}	59.87
Per day	19.12 ± 6.02	22.21 ± 15.09	15.93 ± 6.56	

Figures followed by the same letter in a column are not significantly different ($P = 0.05$) by DMRT.

that of *M. timidus* was significantly lower. The highest fecundity was in *M. timidus*, followed by *M. australis* and *M. igorotus*. With reference to sex ratio, adult emergence and pre and post oviposition periods, *M. australis* and *M. igorotus* were on par; they were significantly lower in *M. timidus*. Our data on fecundity and adult longevity of *M. igorotus* do not agree with the findings of Kulkarni *et al.* (2006). It may be due to difference in rearing methods adopted and ovipositional substrate used. However, higher fecundity and adult longevity recorded in the present study are in agreement with Anon. (2006) and Radhakrishnan and Muraleedharan (1989).

Feeding potential

Consumption of aphids by the adults in their life time was less than that of the larva. The total consumption by the adult was 1.29 (*M. timidus*), 2.09 (*M. igorotus*) and 2.75 (*M. australis*) times more than larva. On the basis of total consumption, *M. igorotus* could be considered as the best predator and it was followed by *M. australis* and *M. timidus* (1018, 798 and 539 aphids, respectively). Anon. (2006) reported high rate of feeding by *M. igorotus* larva and adult. Patnaik *et al.* (1977), Raychaudhuri *et al.* (1981) and Radhakrishnan and Muraleedharan (1989) reported high feeding rate of *M. timidus*. Discrepancies in feeding potential of different hemerobiids during their development could be accounted by variation in environmental factors, host nutrition and inherent capacity of the species.

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Species richness and diversity of butterflies in urban and rural locations of north–east India

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ABSTRACT: North–east India is rich in butterfly fauna. Twelve species of butterflies are reported here as new records from the state of Tripura from where 58 species are known from previous studies. In a spatial scale of 1 km, 22 species belonging to 18 genera of butterflies occurred in urban site and 29 species belonging to 23 genera occurred in the rural site. Twenty two species of butterflies were common for urban and rural sites. Species like common emigrant, common grass yellow and psyche were much more abundant than species like awl and common wanderer.

KEYWORDS: butterflies, species richness, diversity, species ranking, Tripura, North–East India

INTRODUCTION

Butterflies are known to contribute substantially to the growth, maintenance and expansion of flora. This is particularly true of tropical regions where these insects show high abundance and species diversity (Kunte, 1997). Due to richness in vegetation, north–eastern region of India shows rich diversity of butterflies. Kalaisekhar *et al.* (2008) reported 125 species of butterflies from the region (Kunte, 2000). From the State of Tripura 58 species of butterflies were previously recorded (Mandal *et al.*, 2002). In the present study, the species richness and diversity of butterflies in an urban site and a rural site in Tripura were assessed.

MATERIALS AND METHODS

The study areas are located about 67 km apart and comprised a habitat in an urban site, Agartala (23°30′14.81′N latitude, 91°32′03.04′E longitude) and a habitat in a rural site, Sonamura (23°29′04.31″N latitude, 91°17′13.19′E longitude) of Tripura state, both adjoining Bangladesh border.

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Belt transect recording method was used for the census of butterflies (Pollard, 1977; Royer *et al.*, 1998). Two parallel transect lines, each 1 km long and 1 m distance between them, were set up in each study site. In the urban site, transect lines passed through the center of the Agartala city with equal lengths on either side of the city centre and covered locations like human dwellings, public and private gardens, playground and water bodies like ponds and lakes. In the rural location, transect lines traversed through agricultural fields, hutments and houses, waste lands, ditches and canals, and clumps of bamboo and deciduous trees.

Walk census were held on transect lines at 7 day intervals from March 2006 to February 2007. Census was done between 8 am to 11 am. Walking pace was kept slow and uniform. Halts were made along transect lines when it was necessary to collect or identify the species. Butterflies found resting on plants and those in flight were counted and most of these could be identified in the field. Some had to be captured with sweep net for closer examination and identification in field. They were released back. Limited number of specimens had to be examined in the laboratory and some were referred to experts for identification.

Species richness index was calculated by the formula of Menhinick index (D_{Mn}) after Whittker (1967). Comparison of species rank/abundance between the two study sites was done following Kolmogorov–Smirnov two-sample test described by Magurran (2004). Shannon diversity index was calculated following Stiling (2006).

RESULTS AND DISCUSSION

Twenty nine species of butterflies were recorded in the two study sites (Table 1). These belonged to five families. Pieridae and Nymphalidae were represented by 10 species each, Papilionidae by six species, Lycaenidae by two species and Hesperiidae by one species. Twenty two out of 29 species were recorded from both urban and rural sites. Another 7 species were recorded from the rural site only. None of the recorded species occurred exclusively in the urban site. Species richness in the rural area was found to be higher ($D_{Mn} = 1.08$) than in the urban area ($D_{Mn} = 0.96$).

Twelve species (Table 1) were found to be the new records from the Tripura state. As a result of this study, the butterfly fauna of the Tripura state is now known to be 70 species.

A total of 1328 specimens of butterflies were recorded in a year-long census from the two study sites. Out of these, 55.42% and 44.76%, respectively, were recorded from rural and urban sites. Members of Pieridae were most abundant in both sites and that of Hesperiidae showed the least abundance. Members of Nymphalidae and Papilionidae were found to be more abundant in rural site and that of Lycaenidae were found to be more abundant in urban site. In case of Hesperiidae, no difference in abundance was recorded between urban and rural sites (Table 2).

Species wise, common emigrants were found to be the most abundant and common wanderers were the least abundant species in both sites. Among other species, psyche, common grass yellow, danoid egg fly, and mottled emigrant showed relatively higher abundance and species like common gull, caper white and brown awl showed lower

TABLE 1. Species rank and abundance of butterflies recorded by belt transect method in rural and urban sites of Tripura State

Common name	Species name	Species rank	Relative abundance	
			Rural	Urban
Family Nymphalidae				
Common five ring	*Ypthima baldus* (Fabricius)	25	0.0124	–
Common leopard	*Phalanta phalatha* (Drury)*	22	0.0152	–
Peacock pansy	*Junonia almana* (Linnaeus)	15	0.0331	–
Grey pansy	*Junonia atlites* (Linnaeus)	27	0.0096	–
Danoid eggfly	*Hypolimnas misippus* (Linnaeus)*	6	0.0620	0.0529
Common Indian crow	*Euploea core* (Cramer)	12	0.0413	0.0423
Common sailor	*Neptis hylas* Linnaeus	19	0.0193	0.0265
Lemon pansy	*Junonia lemonias* Linnaeus	4	0.0400	0.0643
Plain tiger	*Danaus chrysippus* (Linnaeus)	13	0.0275	0.0378
Striped or common tiger	*Danaus genutia* Cramer	16	0.0275	0.0284
Family Papilionidae				
Tailed jay	*Graphium agamemnon* Linnaeus*	10	0.0375	0.0454
Common mime	*Papilio clytia* Linnaeus	8	0.0275	0.0548
Lime butterfly	*Papilio demoleus* (Linnaeus)	5	0.0358	0.0643
Common mormon	*Papilio polytes* (Linnaeus)	18	0.0262	0.0265
Common jay	*Graphium doson* Felder	20	0.0179	–
Common blue bottle	*Graphium sarpedon* Linnaeus*	26	0.0096	–
Family Pieridae				
Common emigrant	*Catopsilia pomona* Fabricius	1	0.1309	0.1569
Mottled emigrant	*Catopsilia pyranthe* Linnaeus	7	0.0523	0.0473
Common grass yellow	*Eurema hecabe* (Linnaeus)	2	0.1033	0.1512
Common jezebel	*Delias eucharis* (Drury)	14	0.0331	0.0265
Psyche	*Leptosia nina* Fabricius*	3	0.1088	0.1191
Indian cabbage white	*Pieris canidia* (Linnaeus)	17	0.0275	0.0284
Common gull	*Cepora nerissa* Fabricius*	21	0.0152	0.0151
Pioneer/Caper white	*Belenois aurota* (Fabricius)*	23	0.0138	0.0132
Common albatross	*Appias albina* (Boisduval) *	24	0.0138	–
Common wanderer	*Pareronia valeria* Cramer*	29	0.0069	0.0076
Family Lycaenidae				
Tiny grass blue	*Zizula hylax* Fabricius*	11	0.0289	0.0454
Lime blue	*Chilades laius* Stoll*	9	0.0620	0.0473
Family Hesperiidae				
Brown awl	*Badamia exclamationis* Fabricius*	28	0.0083	0.0076

*Species newly recorded from Tripura are indicated by asterisk.

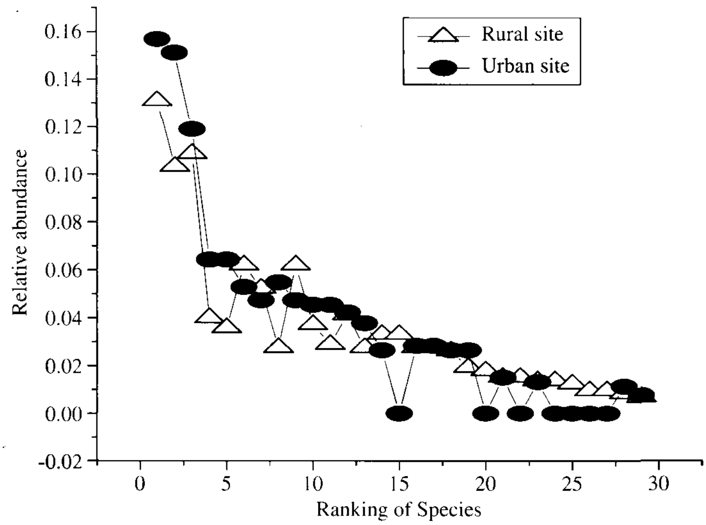

FIGURE 1. Ranking of butterfly species and their relative abundance recorded in rural and urban study sites in Tripura State.

TABLE 2. Number of butterflies under different families recorded in rural and urban study sites in Tripura State

Family	No. of butterflies	
	Rural site	Urban site
Pieridae	367	299
Nymphalidae	204	137
Papilionidae	112	101
Lycaenidae	37	49
Hespiriidae	6	6
Total	736	592

abundance in both sites. Lemon pansy, lime butterflies, tiny grass blue, common mime and lime blue showed relatively higher incidence in the urban site than in the rural site (Table 1).

A comparison of the ranking of species that were recorded in urban and rural sites showed that the pattern of species abundance in the urban site is significantly different ($P < 0.01$) from that in the rural site (Fig. 1; Kolmogprov–Smirnov two-sample test: n_1n_2D: calculated value = 61.76, critical value = 216.92).

Members of four genera, *Appias* (Pieridae), *Ypthima*, *Phalanta* and *Junonia* (Nymphalidae), representing 6 species, were found exclusively at the rural site. Between the two study sites, butterflies were more diverse (29 species belonging to

22 genera) in the rural site than in the urban site (22 species belonging to 18 genera) (Shannon index: rural site: $H_s = 3.023$, urban site: $H_s = 2.734$).

This study has enriched the knowledge on butterflies. Abundance of the common species of butterflies from the two sites was found to be nearly similar. This implies that, in general, environmental conditions essential to foraging, growth and reproduction of these butterflies are available in both urban and rural areas of the Tripura state. Seven species recorded exclusively from the rural site is suggestive of the occurrence of undisturbed ecological niches in the rural site which are not available in the urban site.

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Relative abundance and host plant preference of white grubs in Shimla hills of Northern Himalayas

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ABSTRACT: Light trap studies for assessing relative abundance of root grubs in mid hills of Shimla, Himachal Pradesh, India was carried out during 2008–2009. Eight species of white grubs were encountered in trap catches at Shimla (37°N, 77°E, 2200 m ASL) and Fagu (32°N, 77°E, 2499 m ASL). *Brahmina coriacea* (Hope) was the predominant species at Fagu while *Holotrichia longipennis* (Bl.) and *B. flavosirica*(Bost) were also quite predominant at Shimla. *Anomala lineatopennis* (Bl.) comprised 10% of the population at Shimla but was totally absent in trap catches at Fagu. Emergence of beetles was recorded from June and peak population was observed in July. The number of beetles suddenly dropped to very low levels by beginning of August and none were caught in September at both locations. Maximum rainfall and temperature had significant positive correlation with the emergence of beetles. Among 12 plants species on which beetles were recorded, *Robinia pseudoacacia* L., *Polygonum* sp. and *Pyrus malus* L. were the more preferred.

KEYWORDS: relative abundance, host plant, whitegrubs, potato

INTRODUCTION

Whitegrubs belonging to the family Scarabaeidae of Order Coleoptera are serious polyphagous pests in rainy season crops and distributed throughout country. The adults feed on foliage of many fruit trees and widely growing shrubs while grubs cause serious damage to the root system of many crops. Potato grown as rain fed crop in hills under long day condition suffers serious losses from the whitegrubs. Apple, apricot, pear, plum and walnut have been reported as the preferred hosts of the whitegrub beetle (Gupta *et al.*, 1977). Initially, young grubs feed on the roots of newly planted potato and the second and third instar grubs feed on the underground tubers by making large circular holes in them and thus affect the marketing quality. Yield losses due to whitegrub range between 10.5 to 90.0% in endemic areas situated at higher hills of Uttar Pradesh, Himachal Pradesh, J&K and North–eastern hills (Misra, 1995; Chandla *et al.*, 2001). The beetle emergence starts soon after the pre-monsoon rain in the end

of April and continue till the end of September (Chandel *et al.*, 1997). Light trap has been extensively used for monitoring the beetle population for timing control measure. To combat the problem of whitegrubs in potato crop, it is imperative to understand the species occurring in the region. Information on host preferences of adult in the area also facilitates formulating the strategies of proper pest management. With these objectives studies were conducted at Central Potato Research Institute, Shimla and Fagu during the main potato crop seasons of 2008 and 2009.

The traps were installed in/around potato field, two meters above the ground level. Beetles trapped were counted daily and identified simultaneously. Pooled data of six traps were used for calculation of relative abundance of the beetles. Data on weather parameters viz., temperature, relative humidity and rainfall were obtained from meteorological laboratory at Central Potato Research Institute, Shimla. Simple correlation of these parameters with the white grubs catches was done through path co-efficient analysis suggested by Dewey and Lu (1959).

Host preference studies were conducted for the predominant species, *B. coriacea* under laboratory conditions, adopting choice method. Five starved beetles were released in a card board box with measured quantity of leaves of 12 different host plants in different sets of experiment. The leaf area consumed was recorded after 24 h of release of beetles. The experiment was repeated thrice every year and mean of all the observations was used for comparison.

RESULTS AND DISCUSSION

Species identified

The species composition of whitegrubs and their relative abundance in the two locations are given in Table 1. *Brahmina coriacea* (Hope), *B. flavoserica* (Bost), *B. crinicolis* (Hope), *Holotrichia longipenis* (BL.), *Anomala diimidiata* (Hope), *Anomala* spp. and *Lepidiota stigmata* (F.) were present in both the locations and *A. lineatopennis* (BL.) in Shimla alone.

Population dynamics

From April to September, 1512 and 1056 beetles were collected respectively during 2008 and 2009 at Fagu, whereas at Shimla these numbers were 422 and 314, respectively. It shows that the field population of root grubs was comparatively higher in 2008 at both the places. Fagu located at higher altitude had higher incidence of root grubs than Shimla located at lower altitude.

Relative abundance of species

B. coriacea (62.4% of total catch) was the most predominant species at Fagu (Table 1). It was followed by *B. flavosirica* (10.75%), *A. dimidiata* (10.16%), and *H. longipenis* (6.56%). *L. stigmata* and unidentified *Anomala* spp. constituted less than 1% of total catch at Fagu. In Shimla, *H. longipenis* (29%) and *B. flavoserica* (24%) were

TABLE 1. Relative abundance of different species of white grubs in Shimla hills

Species	No. & % of beetles collected at location & year									
	Fagu					Shimla				
	2008		2009		Mean	2008		2009		Mean
	No.	%	No.	%	(%)	No.	%	No.	%	(%)
Brahmina coriacea (Hope)	1018	67.32	612	57.95	62.64	30	7.10	41	13.13	10.12
Holotrichia longipenis (BL.)	69	4.56	90	8.57	6.56	91	23.9	108	34.39	28.74
Anomala dimidiata (Hope)	154	10.19	107	10.13	10.16	23	6.48	25	7.29	6.88
Brahmina flavoserica (Bost)	148	9.85	113	10.70	10.75	106	25.11	72	22.87	23.99
A. lineatopennis (BL.)	0	0	0	0	0	37	8.76	30	9.73	9.24
B. crinicolis (Hope)	68	4.49	59	5.59	5.05	70	16.58	25	7.96	12.27
Lepidiota stigmata (F.)	5	0.33	13	1.23	0.75	30	7.10	5	1.59	4.35
Anomala spp.	5	0.5	12	1.13	0.32	16	3.79	3	0.95	2.74
Others	45	2.97	50	4.73	3.85	19	4.56	5	1.59	2.88

TABLE 2. Month wise proportion of white grub beetles collected in the light traps at two locations during 2008–2009

Month	Percentage of total catch (%)					
	Fagu			Shimla		
	2008	2009	Mean (%)	2008	2009	Mean (%)
May	4.49	3.97	4.23	2.36	1.9	2.13
June	45.23	39.67	42.45	39.81	42.99	41.40
July	46.23	54.57	50.40	50.23	50.53	50.41
August	3.04	1.42	2.23	5.9	4.4	5.15
September	0.99	0.37	0.68	1.6	0.1	0.85
October	0.00	0.00	0	0.0	0.0	0

TABLE 3. Acceptability of selected plant species for feeding by *Brahmina coriacea*, in a laboratory study

Plant species	Common name	Mean ± SE leaf area consumed (mm^2)
Robinia pseudoacacia L.	Robinia	113 ± 9
Polygonum sp.	Polygonum	98 ± 4
Pyrus malus L.	Walnut	58 ± 3
Prunus persica. L.	Peach	42 ± 2
Julgans rigia L.	Apple	38 ± 2
Khathi sp.	Khathi	36 ± 3
Rosa indica L.	Rose	31 ± 2
Pyrus communis L.	Pear	28 ± 1
Zea mays L.	Maize	19 ± 3
Dahlia pinnata L.	Dahlia	16 ± 1
Zinnia elegan L.	Zinnia	11 ± 2
Quercus leucotrichophora A.	Oak	9 ± 1

the predominant species. *B. crinicolis* (12%) followed by *B. coriacea* (10%), *A. lineatopennis* (9.24%) and *A. dimidiata* (6.88%) may be considered as the important species of root grubs. *A. lineatopennis*which formed 9% of total catch was absent in Fagu. *L. stigmata* and unidentified *Anomala* spp. recorded less than 1% of total catch at Shimla. Six species of whitegrubs i.e. *B. coriacea*, *H. longipenis*, *A. diimidiata B. flavoserica*, *B. crinicolis*, and *Anomala* spp. infesting potato were reported from this region earlier (Misra and Chandel, 2003).

The month vise catches are shown in Table 2. Beetles started appearing in the trap after pre-monsoon rain in May and continued up to the end of September with peak in June /July in both the years. Singh and Dogra (1982), Chandel *et al.* (1997) and Gupta *et al.* (1977) also reported the emergence of beetles in the last week of May at Shimla. The correlation studies revealed a significant positive association with maximum rainfall ($r = 0.44$) and relative humidity ($r = 0.55$). Maximum temperature showed significant negative influence ($r = -0.48$). Minimum temperature did not

show significant correlation with population. Our findings are in agreement with Chandel *et al.* (2003).

Host preference studies (Table 3) revealed that *Robinia pseudoacacia* and *Polygonum* spp. were the most preferred with 113.5 mm^2 and 98 mm^2 mean leaf area consumed per beetle per day, respectively, followed by *Pyrus malus* with 58 mm^2 leaf area consumed. *Polygonum* spp. was also reported earlier as most preferred host of *B. coriacea* in Shimla hills (Chandel *et al.*, 2003).

Our results suggest that the installation of light traps during April to September can be one of the effective components in IPM of white grubs in potato fields as it helps in mass trapping of beetles leading to low population of grubs in the field and it also helps to schedule pesticide sprays.

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Species diversity and incidence of winged aphids (Hemiptera: Aphididae) in water traps in Tripura, north-east India

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ABSTRACT: In a study at Tripura, north-east India, 2247 winged aphids belonging to 17 species were collected in two water traps that were operated for 12 months. Species of subfamily Aphidinae dominated the collection and *Aphis spiraecola* ranked first in abundance. Three species of agricultural importance namely, *Aphis craccivora*, *Lipaphis pseudobrassicae* and *A. gossypii* ranked second, third and fourth, respectively, based on their relative abundance. Winged morph of aphid species known to feed on wild plants and forest trees were less preponderant. Importance of water traps in monitoring the aphid population of crop infesting species is discussed.

KEYWORDS: winged aphids, diversity, incidence, water traps

INTRODUCTION

Winged morph is the chief means of distribution of aphids in space and time. In regions of cold winter, aphids show holocyclic life cycle, that is, single generation of sexual reproduction in winter is followed by several generations of asexual reproduction in spring and summer. These species show seasonal migration in spring from winter hosts to summer hosts and return migration in autumn to winter host. In contrast, in warm regions, aphids reproduce by asexual means only and show anholocyclic life cycle. These species show periodical dispersal of their population in response to changes in climate and host quality, crowding effects and natural enemies (Dixon, 1998; Dixon and Agarwala, 1999; Agarwala, 2007). Several studies have reported the importance of winged morph in the distribution of aphids (Tatchell, 1982; Rajendran and Ram, 1990; Howard and Dixon, 1992). This is particularly true of aphids that are vectors of viral diseases in crop plants (Kishore and Phadke, 1988; Singh *et al.*, 1990; Agarwala, 1995; Sharon *et al.*, 2003). There is scanty information about the seasonal abundance

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of winged aphids from north-east India (Agarwala and Dasgupta, 1986; Agarwala and Bhattacharya, 1994) from where about 361 species have been recorded (Raychaudhuri, 1980; Agarwala and Ghosh, 1984). These include 149 species that infest crops and other economically important plants (Ghosh, 1974; Agarwala and Raychaudhuri, 1981). Therefore, a study was undertaken to record the species diversity and incidence pattern of air-borne aphids in different months of a year in the hot and humid climate of Tripura State in north-east India.

MATERIALS AND METHODS

Incidence of winged aphids was monitored in the Tripura University Campus at Suryamaninagar, Tripura West from March 2006 to February 2007 through water traps (24″ long × 15″ wide × 10″ deep). Traps were coloured yellow inside and green on outsides and placed at the ground level. Two such traps, kept 40 m apart, were placed in a cultivated piece of land surrounded by degraded forest comprising of bushes, bamboo clumps, grasses and herbaceous weeds. Traps were filled with fresh water up to 2 cm short of the brim. Aphids were collected at an interval of 4 days when the remaining water in the traps was replaced by fresh water. Aphids from these collections were counted and preserved in 70% alcohol. All aphid specimens were mounted individually on slides for microscopic study following the method of Raychaudhuri (1980) and identified. In order to determine month-wise incidence of winged morph of different species, number of aphids of respective species collected in a month were pooled and their relative abundance and ranking determined.

RESULTS

Species diversity

A total of 190 collections of trapped insects were made from the two traps during 12 months of monitoring. These comprised of 2247 winged aphids belonging to 17 species under 14 genera and 3 subfamilies. Of these, 2166 aphids (96.4%) belonged to 13 species under the subfamily Aphidinae, 15 aphids (0.67%) belonged to two species of Greenideinae, and the rest (66 aphids) (2.93%) belonged to two species of Hormaphidinae.

Species diversity was much higher (8–10 species) in the months of December to April when several crops were present in fields. Number of species collected declined in the following months of hot summer and monsoon, and the minimum of two species was recorded in the months of September and October (Fig. 1).

Incidence of winged aphids

Incidence of winged aphids was much higher in cooler and drier months (November to February) than in hotter and rainy months (March to October) (Fig. 2). The highest incidence of winged aphids (25.10%; average temperature 21.8°C) was recorded in February and the lowest (0.89%; average temperature 25.95°C) in October. In rest of

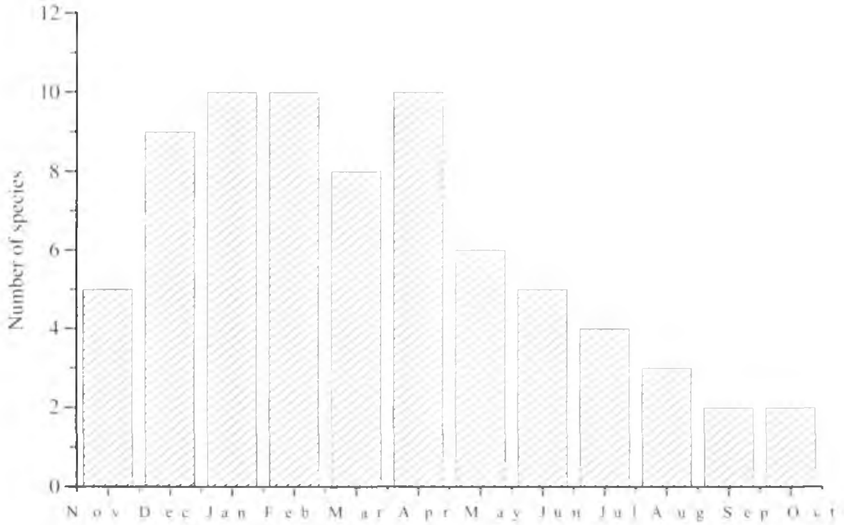

FIGURE 1. Number of aphid species recorded in water traps in different months.

the months, incidence of winged aphids varied in the range of 2.27% to 22.21% of the total number of winged aphids collected in water traps. A positive correlation was found between the incidence of winged aphids and the prevailing temperature in a month ($r = 0.821$).

The weed (*Chromolaena odorata*) infesting species, *A. spiraecola* Patch, occurred throughout the year and the beans infesting species, *A. craccivora* Koch, occurred in several months (Fig. 3). The mustard aphid, *Lipaphis pseudobrassicae* (Kaltenbach), was active in cooler months during rabi cropping season. *Aphis gossypii* Glover, the most polyphagous of the 17 species collected in this study was active in nine of the 12 months.

Table 1 presents a list of aphid species according to their rank (R) based on relative abundance (RA). *Aphis spiraecola* ranked first (RA = 27.59%). Other aphid species that contributed 10% or more of the total abundance were *A. craccivora* (24.52%), *L. pseudobrassicae* (18.74%) and *A. gossypii* (10.10%). *Myzus persicae*, *Pentalonia nigronervosa*, *Ceratovacuna lanigera* and 10 other species ranked lower and together contributed the remaining 19.05% of the total catch of winged aphids. Four species of the genus *Aphis* comprised 69.2% of the total aphid incidence.

DISCUSSION

This study showed that in water traps attracted aphid species that infest various kinds of host plants, including seasonal crops, perennial edible plants, bamboos and other plants that occur in the wild. Prevailing temperature influenced the production of winged morph as well as species diversity of aphids. Cooler and drier months

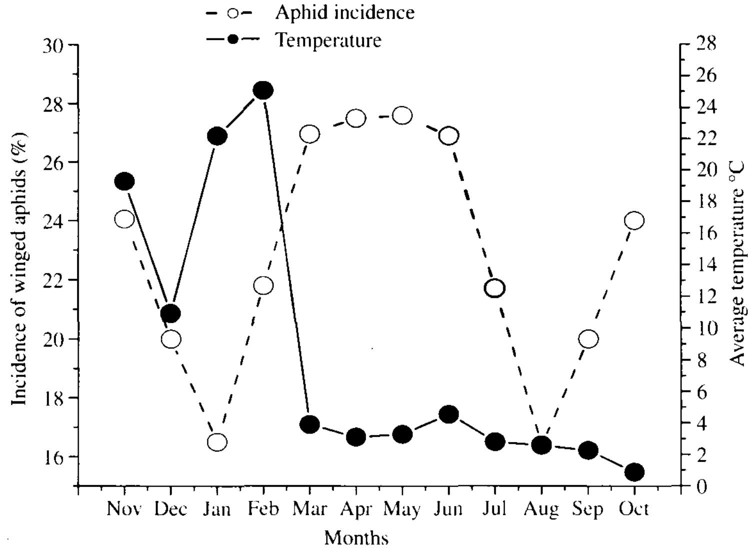

FIGURE 2. Incidence of winged aphids and average temperature in different months.

TABLE 1. Relative abundance and ranking of aphid species recorded in water traps

Species	Relative abundance (%)	Species ranking
Aphis spiraecola Patch	27.59	1
Aphis craccivora Koch	24.52	2
Lipaphis pseudobrassicae (Kaltenbach)	18.74	3
Aphis gossypii Glover	10.10	4
Aphis nasturtii Kaltenbach	6.99	5
Myzus persicae (Sulzer)	2.76	6
Pentalonia nigronervosa Coquerel	2.09	7
Ceratovacuna lanigera Zehntner	1.82	8
Capitophorus indicus Ghosh and Raychaudhuri	1.25	9
Macrosiphum miscanthi Takahashi	1.07	10
Ceratovacuna silvestrii (Takahashi)	0.80	11
Rhopalosiphum maidis (Fitch)	0.58	12
Acrythosiphon pisum (Harris)	0.44	13
Schoutedenia lutea (van der Goot)	0.44	14
Brachycaudus helichrysi (Kaltenbach)	0.36	15
Rhopalosiphum padi (Linnaeus)	0.22	16
Cervaphis rappardi indica Basu	0.22	17

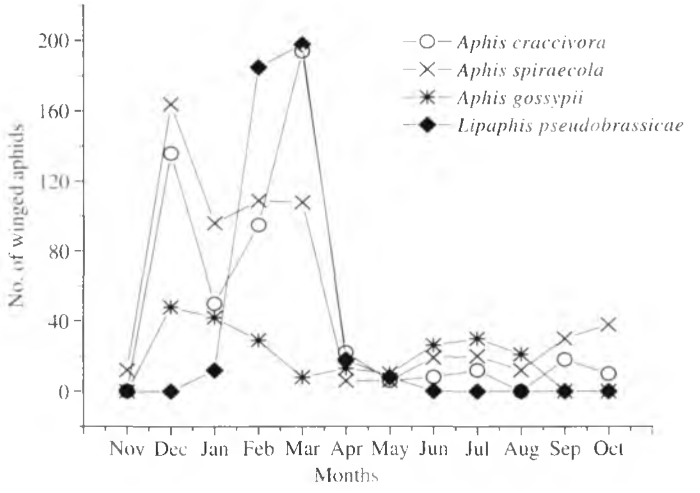

FIGURE 3. Relative abundance of aphids of the four dominant species in different months.

favoured the occurrence of winged morph. *A. spiraecola* and its weed host plant *Chromolaena odorata*, both, occurred throughout the year in the study area with higher incidence recorded in cooler months. Phyto-geographically, Tripura lies in hot and humid region and is rich in floral diversity (Deb, 1981, 1983; Chakrabarty *et al.*, 2004). It is intriguing, however, that winged morphs of aphids belonging to subfamilies Chaitophorinae, Drepanosipinae, Lachninae and Pemphiginae, which are characteristically associated with tree species were not found in this study. This could be attributed to low abundance of tree species and their scattered distribution caused by extensive agriculture, horticulture and other human activities. Monophagous tree-dwelling aphids prefer to infest trees that show higher apparency or abundance per unit area (Dixon, 1998). All the aphid species recorded in this study are known to reproduce by asexual means in this part of Asia. Therefore, winged morph of these species collected in water traps may be in their dispersal mode from one host plant to another host plant.

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Recharacterization of genus *Nepita* Moore (Lepidoptera: Arctiidae: Lithosiinae)

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ABSTRACT: A monotypic genus, *Nepita* Moore is recharacterized by incorporating external male and female genitalic attributes in its diagnosis. Male genitalic characters like uncus, vinculum, valvae, transtilla, aedeagus and female genitalic characters like corpus bursae, ductus bursae, apophyses, and papilla analis have been included in the revised diagnosis of the genus.

KEYWORDS: Lepidoptera, Arctiidae, Lithosiinae, *Nepita* Moore, recharacterization

INTRODUCTION

The genus, *Nepita* was proposed by Moore in 1860 with *conferta* Walker from Sri Lanka as its type species. Hampson (1894) in his studies on the genus *Nepita* Moore, placed three different genera i.e., *Pitane* Walker, *Cabarda* Walker, and *Adites* Moore under its synonymy. In his publication, Hampson (1894) studied three species i.e., *conferta* Walker, *hilaris* Walker and *frigida* Walker under *Nepita* Moore. Later, in 1900, Hampson synonymised the genus *Nepita* Moore under *Asura* Walker. *Nepita* was established as the objective replacement name for *Pitane* Walker by Watson *et al.* in 1980. Once again in 2001, Holloway hinted the revival of genus *Nepita* Moore (=*Pitane* Walker Praeocc.) with the removal of two species i.e. *hilaris* Walker and *frigida* Walker to some other genera. As it stands, the genus *Nepita* Moore is a monotypic taxon which is being recharacterized here by incorporating the male and female genitalic characters in its diagnosis.

MATERIALS AND METHODS

For the present study a large sample of 53 specimens of this genus were collected from different localities of Western Ghats. Some representatives of the species under reference were also collected during day time. The whole population belongs to

single species *conferta* Walker. The male and female genitalic structures were studied, described and illustrated. The method proposed by Common (1970) and advocated by Zimmerman (1978) was followed for the preparation of permanent slides of fore and hindwings. For the study of external male genitalia, methodology given by Robinson (1976) was followed.

RESULTS AND DISCUSSION

Genus *Nepita* Moore

Moore, 1860, *Cat. Lep. Ins. Mus. Nat. Hist.*, **2**: 302.

Type species : *Pitane conferta* Walker

Distribution : India; Sri Lanka; Mayanmar and Borneo.

Diagnosis:

Labial palpi porrect. Antennae bipectinate in males and simple in females. Forewing with vein R_1 anastomoses with Sc and separates to meet costa; R_2 from cell; R_3, R_4 and R_5 stalked; M_1 beyond upper angle of cell; M_2 near lower angle. Hindwing with vein $Sc + R_1$ originating towards upper angle; Rs and M_1 stalked; M_2 present; M_3 and Cu_1 from lower angle of cell. Male genitalia with uncus short, broad at base, narrowing towards distal end, slightly curved; acrotergite absent; fenestrula present; vinculum shorter than tegumen; saccus developed; valvae with costa and sacculus well defined, ampulla present, cucullus and valvula simple. Transtilla bar-shaped; juxta almost rectangular; aedeagus short and broad; vesica with a strong sclerotization; ductus ejaculatorius entering subapically. Female genitalia with corpus bursae obliquely rounded, weakly sclerotized; ductus bursae short, membranous; anterior apophyses shorter than posterior apophyses; papilla analis setosed with moderately long setae.

Nepita conferta (Walker) (Fig. 1)

Pitane conferta Walker, 1854, *Cat. Lep. Het.*, **2**: 533.
Nepita anila Moore, 1859, *Lep. E.L Co.*, **2**: 302.
Nepita signata Walker, 1864, *Cat. Lep. Het.*, **31**: 240.
Nepita aegrota Butler, 1877, *Trans. Ent. Soc.*, **1877**: 336.
Nepita conferta Walker, 1894, *Fauna Br. Ind. Moths*, **2**: 106.
Asura conferta Walker, 1900, *Cat. Lep. Phal.*, **2**: 428.
Nepita conferta Walker, 2001, *Moths of Borneo*, **7**: 366.

Head with frons and vertex orange yellow, central area furnished with black scales. Antennae bipectinate in males, simple in females; scape and pedicel orange yellow; basal half of shaft covered with orange scales, second half black. Eyes yellowish green, densely spotted with black. Labial palpi porrect; furnished with orange yellow scales.

Thorax, collar and tegula orange yellow, spotted with black; pectus orange. Forewing with ground colour orange yellow; two or three sub basal spots; antemedial and medial wavy black bands, conjoint to each other at median nervure; black spot

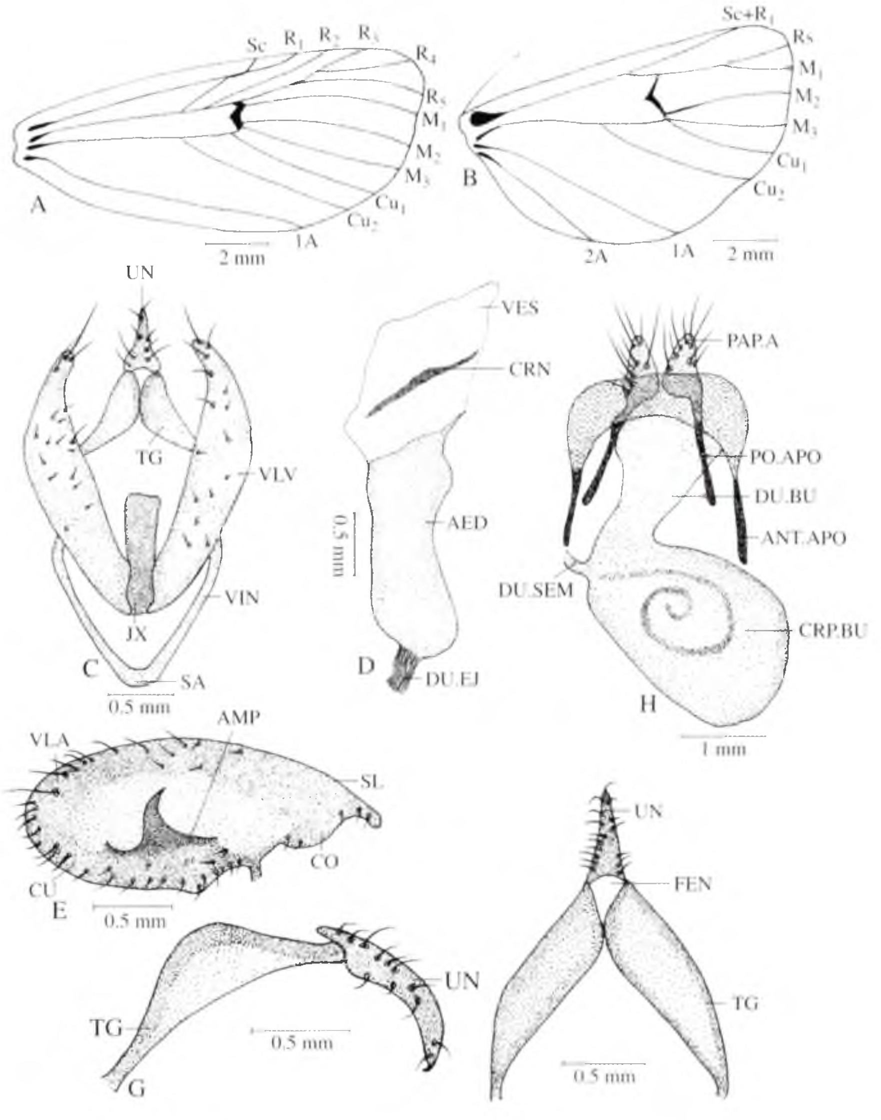

FIGURE 1. *Nepita conferta* (Walker): A, Forewing; B, Hindwing; C, Male genitalia; D, Aedeagus; E, Valva (right); F, Uncus with Tegumen (dorsal view); G, Uncus with Tegumen (lateral view); H, Female genitalia.

1A, First anal vein; 2A, Second anal vein; AED, Aedeagus; AMP+HRP, Ampulla & Harpe (fused); ANT.APO, Anterior apophyses; CO, Costa; CRN, Cornuti; CRP.BU, Corpus Bursae; CU, Cucullus; CU_1, First cubital vein; CU_2, Second cubital vein; DU.BU, Ductus Bursae; DU.EJ, Ductus Ejaculatorius; DU.SEM, Ductus Seminalis; FEN, Fenestrula; JX, Juxta; M_1, First median vein; M_2, Second median vein; M_3, Third median vein; PAP.A, Papilla Analis; PO.APO, Posterior apophyses; R_1, First radial vein; R_2, Second radial vein; R_3, Third radial vein ; R_4, Fourth radial vein; R_5, Fifth radial vein; RS, Radial Sector; SA, Saccus; SC, Subcosta; $SC + R_1$, Stalk of $SC + R_1$; SIG, Signum; SL, Sacculus; TG, Tegumen; UN, Uncus; VES, Vesica; VIN, Vinculum; VLA, Valvula; VLV, Valva.

at end of cell; a postmedial wavy black band, excurved at discocellular; a wavy submarginal band with two excurvations approaching margin; underside with ground colour orange yellow, markings obsolete except on marginal area; fringe black; vein R_1 originating from cell, anastomoses with Sc and separates to meet costa; R_2 from cell; R_3, R_4 and R_5 stalked; M_1 slightly beyond upper angle; M_2 near lower angle of cell; M_3 from angle of cell; Cu_1 before lower angle; Cu_2 from middle of cell. Hindwing with ground colour orange yellow; marginal band broad; underside same with black markings obsolete; fringe black; vein $Sc + R_1$ originating towards upper angle of cell; Rs and M_1 stalked; M_2 near angle of cell; M_3 and Cu_1 from lower angle; Cu_2 from middle of cell. Legs orange, spotted with black; hind tibia with two pair of spurs.

Abdomen black; underside and tuft orange. Male genitalia as described in diagnosis of genus. Female genitalia as described in diagnosis of genus.

Wing span: Male 24–26 mm; female 32–34 mm.

MATERIAL EXAMINED

Gujarat: Ahwa (520 m), 28.ix.05 - 3♂♂5♀♀; Waghai (180 m), 27.ix.05 - 1♀; Saputara (970 m), 29.ix.05 - 1♂ 1♀.

Maharashtra: Malshej Ghat (690 m), 1.x.05 - 2♀♀; SGNP (Mumbai) (80 m), 3.x.05 - 1♂ 1♀, 4.x.05 - 1♂.

Karnataka: Bhagamandala (900 m), 29.vii.04 - 2♂♂ 4♀♀; Ganeshgudi (480 m), 19.vii.04 - 1♂ 1♀, 21.vii.04 - 1♂ 1♀, 13.x.05 - 5♂♂ 2♀♀; Medikeri (1100 m), 13.xi.05 - 1♀, 24.ix.03 - 1♂; Jogfalls (480 m), 22.vii.04 - 1♂; Kallathyfalls (960 m), 23.vii.04 - 1♂, 24.vii.04 - 1♂.

Tamil Nadu: Gudalur (900 m), 29.ix.03 - 1♀.

Kerala: Mukkali (560 m), 18.ix.04-4♀♀, 20.ix.04 - 2♀♀, 21.ix.04 - 2♀♀; Ranni (40 m), 6.ix.04 - 2♀♀; Chendruni (70 m), 3.ix.04 - 2♀♀; Coonoor (1880 m), 2.x.03 - 1♂, Agali (520 m), 6.x.03 - 1♂.

Old distribution: India: North India, Mumbai, Poona, Belgaum, Nilgiri Hills (Tamil Nadu), Coimbatore; Sri Lanka.

DISCUSSION

The genus *Nepita* Moore is a monobasic genus and was characterized by Moore in 1860 and further studied by Hampson in 1894 on the basis of a few external attributes which included general maculation and wing venation. The external genitalic features are highly species specific in family Arctiidae. The male and female genitalic attributes are included in the revised diagnosis of the genus.

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Glyptotermes roonwali (Isoptera: Kalotermitidae), a new species from India

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ABSTRACT: A new species of the termite genus, *Glyptotermes* Froggatt from India is described. Comparison with closely related species and a key to the species of *Glyptotermes* recorded from the Indian sub-region are given.

KEYWORDS: Isoptera, Kalotermitidae, new species, *Glyptotermes roonwali*

INTRODUCTION

Termites of the family Kalotermitidae, except *Paraneotermes simplicicornis* Banks, Light (1937), are exclusively wood infesting and have no connection with soil. They are serious pests of forestry and cause extensive damage to wood-work in buildings. These termites construct nests in dead or live portion of standing trees, fallen logs and wooden structures in buildings. Only two castes (reproductives and soldiers) are found in this family; the worker caste is absent and its functions are performed by the immature reproductives called psuedoworkers. The family Kalotermitidae is cosmopolitan in distribution represented in almost all the zoogeographical regions except Palaearctic and Nearctic. There are 24 genera and 320 species of which only 9 genera and 43 species are available in the Indian sub-region Roonwal and Chhotani (1989).

Snyder (1949) recorded 45 living and one fossil species of the genus *Glyptotermes* from different zoogeographical regions. Later, Chhotani (1975) reported 73 living and one fossil species, taking into account all the species described till then. Subsequently, 27 more living species have been described: 5 from the Indian sub-region, 7 from Sabah (Malaysia), one each from Thailand and Japan and 13 from China. From the Indian sub-region, 12 species are known (Roonwal and Chhotani, 1989): *Glyptotermes almorensis* Gardner (India), *G. arshadi* Akhtar (Bangladesh), *G. ceylonicus* Holmgren (Sri Lanka), *G. coorgensis* Holmgren and Holmgren (India), *G. dilatatus* (Bugnion

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and Popoff) (Sri Lanka), *G. minutus* Kemner (Sri Lanka), *G. nicobarensis* (Maiti and Chakraborty) (India), *G. sensarmai* Maiti (India), *G. teknafensis* Akhtar (Bangladesh & India), *G. tikaderi* Chhotani and Bose (India), *G. tripurensis* Thakur (India), and *G. ukhiaensis* Akhtar (Bangladesh & India).

KEY TO THE SPECIES OF *GLYPTOTERMES* FROM THE INDIAN SUBREGION: SOLDIER CASTE

1(8) Larger species: Total body-length 6.5–11.2, head-length to base of mandibles 1.90–3.5, head-width 1.30–2.05 mm.

2(7) Frons sharply inclined in front, angle of inclination more than 60°.

3(6) Head-length to base of mandibles 2.6–3.5, head-width 1.5–2.05 mm; frontal protuberances on head broad and weak and antero-lateral corners of head rounded; mandibles shorter in comparison to head.

4(5) Larger species: head-length to base of mandibles 3.2–3.5, head-width 1.90–2.05 mm; antennae 14 to 15-segmented; mandibles longer in comparison to head-length (index left mandible-length/head-length to base of mandibles 0.44–0.46 . . . . *tikaderi*.

5(4) Smaller species: Head-length to base of mandibles 2.67–3.00, head-width 1.50–1.67 mm; antennae 12-segmented; mandibles shorter in comparison to head-length (index left mandible-length/head-length to base of mandibles 0.33–0.36 . . . . *ceylonicus*.

6(3) Head-length to base of mandibles 1.90–2.33, head-width 1.30–1.40 mm; frontal protuberances on head sharp and prominent and antero-lateral corners pointed; mandibles longer in comparison to head . . . . *dilatatus*.

7(2) Frons less so sharply inclined, angle of inclination 45°–50° [Head-length without mandibles 1.93–2.27, head-width 1.25–1.40 mm] . . . . . . *teknafensis*.

8(1) Smaller species: Total body-length 4.0–7.0 mm, head-length to base of mandibles 1.13–1.73, head-width 0.80–1.20 mm.

9(16) Head width less than 1.00 mm.

10(11) Eyes absent; tenth abdominal tergite not strongly sclerotised; antero-lateral corners of head sharply pointed . . . . *arshadi*.

11(10) Eyes present; tenth abdominal tergite not strongly sclerotised; antero-lateral corners of head rounded.

12(13) Ocelli absent and epicranial sutures faint or absent . . . . *ukhiaensis*.

13(12) Ocelli present and epicranial sutures prominent.

14(15) Postmentum with broader portion large and sharply and strongly incurving at waist . . . . *tripurensis*.

15(14) Postmentum with broader portion small and gradually and weakly incurving at waist . . . . *minutus*.

16(9) Head width more than 1.00 mm.

17(20) Antero-lateral corners of head-capsule sharply pointed in front.

18(19) Mandibles with prominent basal humps on outer margin and comparatively weakly incurved anteriorly; margin between 2nd and 3rd marginal teeth of left mandible sharp, angularly incurved; ocelli present; postmentum broader at waist .... *coorgensis*.

19(18) Mandibles with weaker basal humps on outer margin and comparatively strongly incurved anteriorly; margin between 2nd and 3rd marginal teeth of left mandible roundly incurved; ocelli absent; postmentum narrower at waist .... *sensarmai*.

20(17) Antero-lateral corners of head-capsule rounded in front.

21(22) Head comparative to length narrower (width/length to base of mandibles 0.59–0.66); Y-suture complete, lateral arms distinct; mandibles shorter in comparison to head-length to base of mandibles, index 0.53–0.41 .... *nicobarensis*.

22(21) Head comparative to length wider (width/length to base of mandibles 0.67–0.77); Y-suture incomplete; lateral arms indistinct; mandibles larger in comparison to head-length to base of mandibles, index mandible length/bead-length 0.45–0.47.

23(24) Comparatively larger species. Total body length 4.8–5.7 mm; head length to lateral base of mandibles 1.43–1.73 mm; head width 1.07–1.13 mm. .... *almorensis*.

24(23) Smaller species. Total body length 4.48–4.86 mm; head length to lateral base of mandibles 1.20–1.28 mm; head width 0.90–0.92 mm.......... *roonwali*.

***Glyptotermes roonwali* n. sp.**

(Figs. 1 and 2; Tables 1 and 2)

Material: One vial with several S. and Ps. from Phoolbagh, Haldwani, Uttarakhand, coll. R. K. Thakur, 9-10-1993.

Description:

Imago: Unknown

Soldier: (Fig. 1, Table 1)

General: Head-capsule, labrum and postmentum rusty yellowish to reddish brown, paler posteriorly and darker anteriorly; mandibles blackish; pronotum yellowish brown; antennae, legs and abdomen pale yellowish brown; 10th abdominal tergite highly sclerotised and yellowish brown, much distinct from the rest of the tergites. Head-capsule and body sparsely pilose. Total body length 4.48–4.86 mm.

Head: Head-capsule subrectangular; fairly thick, longer than broad; weakly phragmotic, with frontal area gently sloping anteriorly; weakly bilobed, with V-shaped

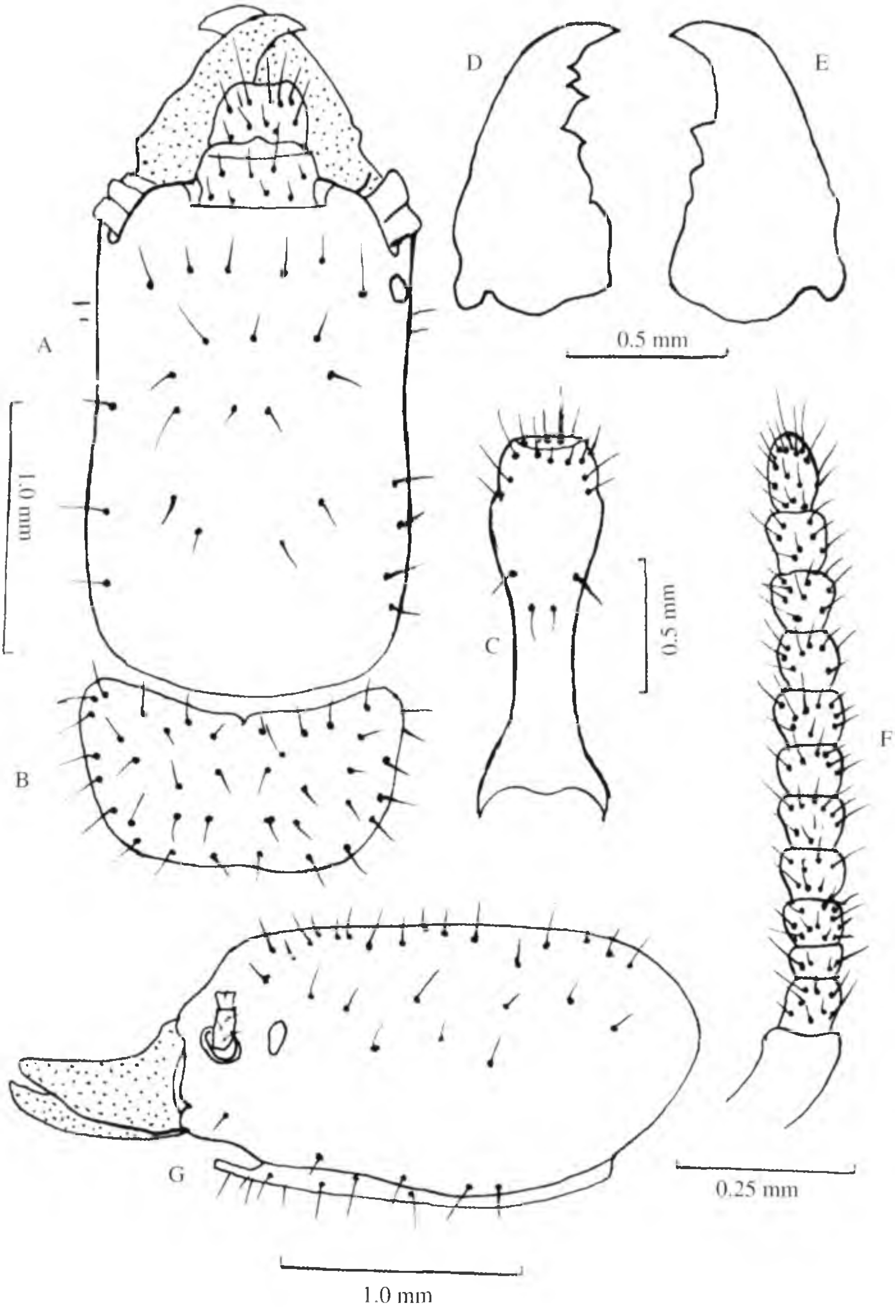

FIGURE 1. *Glyptotermes roonwali* n. sp. Soldier Caste: A, Head dorsal view; B, Pronotum dorsal view; C. Postmentum *in situ*; D, Right mandible; E, Left mandible; F, Right antenna; G, Head side view.

TABLE 1. Body measurements (in mm) and indices of ten soldiers of *Glyptotermes roonwali* n. sp.

Body-Parts	Range	Mean	Holotype
I. General			
Total body length	4.48–4.86	4.67	4.48
II. Head			
Head-length with mandibles	1.70–2.02	1.86	1.70
Head-length to lateral base of mandibles	1.20–1.28	1.24	1.20
Maximum width of head	0.90–0.92	0.91	0.90
Height of head	0.72–0.78	0.75	0.72
Head-index-I (Head-width/head-length to lateral base of mandibles)	0.66–0.74	0.70	0.66
Head-index-II (height/width of head)	0.80–0.82	0.81	0.80
Head-index-III(height of head/head-length to lateral base of mandibles)	0.56–0.58	0.57	0.56
Maximum diameter of eye	0.15–0.20	0.18	0.15
Minimum diameter of eye	0.10–0.12	0.11	0.10
Minimum eye-ocellus distance	0.92–1.12	1.02	0.92
Length of mandibles			
(a) left mandible	0.62–0.68	0.65	0.62
(b) right mandible	0.62–0.68	0.65	0.62
Head-mandibular index-I (Left mandible length/head to lateral base of mandible)	0.50–0.53	0.51	0.50
Minimum (median) length of postmentum	0.78–0.86	0.82	0.78
Maximum width of postmentum	0.36–0.40	0.38	0.36
Minimum width of postmentum	0.16–0.20	0.18	0.16
III Thorax			
Length of Pronotum	0.42–0.48	0.45	0.42
Maximum width of Pronotum	0.78–0.84	0.81	0.78
Pronotum-head width index (Pronotum width/head width)	0.88–0.92	0.90	0.88

shallow depression between the lobes; sides subparallel, weakly converging near the posterior region of head-capsule; posterior margin broadly rounded; epicranial suture distinct, posterior arm extending up to occiput. *Eyes*: Unpigmented, oval shaped, situated near the antennal carinae. *Ocelli*: of pinhole size, whitish; separated from eyes by almost half the long diameter of eyes. *Antennae*: With 11–12 segments; segment 2 about half of 1;3 shorter than 2, subequal to or slightly longer than 4, sometimes subdivided. *Labrum*: Subrect-angular, distinctly wider than long; lateral sides subparallel; anterior margin weakly convex. *Clypeus*: Post-clypeus indistinctly separated from frons; anterior margin weakly convex. Anteclypeus subtrapezoid, broad and whitish; anterior margin sub-straight. *Mandibles*: Stoutly built, short; length almost half the head-length to lateral base of mandibles (head-mandibular index 0.48–0.53); with a weak basal hump; apices weakly hoked. Left mandible with 3 marginal

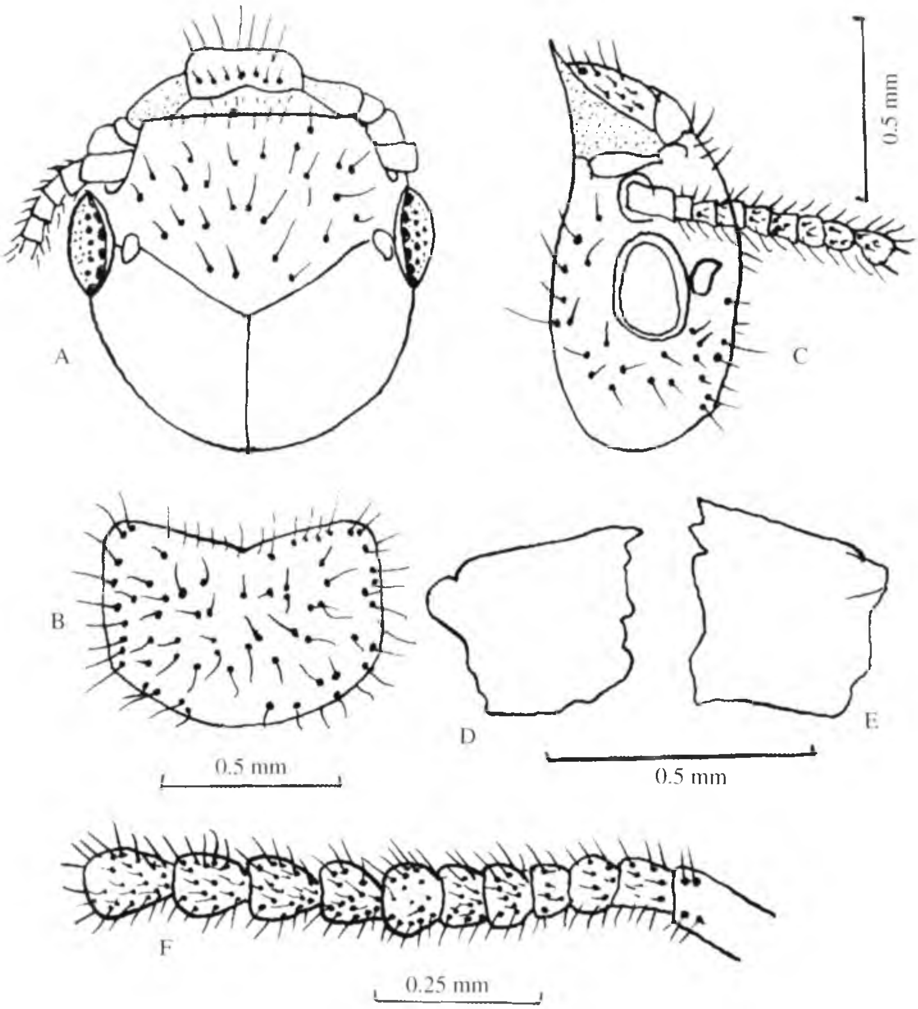

FIGURE 2. *Glyptotermes roonwali* n. sp. Worker Caste: A, Head dorsal view; B, Pronotum dorsal view; C, Right mandible; D, Left mandible; E, Right antenna.

teeth; 1st marginal small; 2 slightly longer than 1st, but subequal to 3; 3 separated from 2 by a deep cavity. Right mandible with one to two larger subtriangular teeth lying in the median third of mandible. *Postmentum*: Club shaped; widest near the apical third, narrowest in the basal third, maximum width slightly more than twice the minimum width.

Thorax: Pronotum: Subtrapezoid; narrower than head-width; anterior margin deeply concave; lateral margin weakly convergine posteriorly; posterior margin

TABLE 2. Body measurements (in mm) of *Glyptotermes roonwali* n. sp.

Body-Parts	Range	Mean
I. General		
Total body length	3.35–4.70	4.45
II. Head		
Length of head to tip of labrum	0.95–1.10	1.00
Head-length to lateral base of mandibles	0.70–0.85	0.77
Maximum width of head	0.80–0.90	0.86
Height of head	0.48–0.55	0.53
III Thorax		
Length of Pronotum	0.35–0.48	0.41
Width or Pronotum	0.70–0.80	074

substraight with a weak depression in the middle. *Mesonotum*: As wide as or slightly than Pronotum; posterior margin substraight. Metanotum: Wider than prootum; posterior margin substraight. *Legs*: Moderately long; femora comparatively swollen; tibial spurs 3: 3: 3; tarsi 4-segmented.

Abdomen: Subcylindrical; 10th segment highly sclerotised and pigmented; fairly hairy; ceri 2-segmented and hairy; length ca 0.08–0.10 mm Styli single jointed, cone shaped; length ca 0.05–0.08 mm.

Pseudoworkers: (Fig. 2, Table 2)

General: Head-capsule, antennae, pronotum and legs yellowish white, with a milky white glandular area in the frons region; postclypeus, labrum and toothed margins of mandibles brownish; abdomen translucent, dirtly brown. Head and body sparsely hairy. Total body-length ca. 3.36–4.70 mm.

Head: Head-capsule suboval, only slightly wider long widest across the eyes; sides weakly convex, converging posteriorly to narrowly rounded posterior margin; epicranial suture absent. Eyes: Rudimentry, suboval; either translucent or pale brownish (whenpigmented) *Ocelli*: absent. *Antennae*: With 9–11 segments; segment 1 subcylindrical; 2 cylindrical, length variable, distinctly longer than 3 in 9–10 segmented antennae or subequal to 3; 4 shortest; segments 5 to penultimate wider than long, almost of equal length; last come shaped, narrower than preceding segments. *Clypeus*: Postelypeus subrectangular, flat; beset with hairs on the body. Anteclypeus subtrapeziod and apilose.

Mandibles: Left mandible with an apical and two marginal teeth on the inner margin; apical finger like; Ist marginal small, sub-triangular, its anterior edge considerably shorter than its posterior edge; molar area rounded. Right mandible with an apical and two marginal teeth; apical triangular, a little longer than 1st marginal; 1st marginal triangular, approximated to apical, its anterior edge either smaller or subequal to molar plate.

Thorax: *Pronotum*: Flat; subtriangular and broader than long; distinctly narrower than head-width; anterior margin deeply concave; lateral sides weakly converging posteriorly, somewhat sloping downward; posterior margin substraight. *Mesonotum*: Subequal to or slightly broader than measonotum; posterior margin substraight.

Abdomen: oblong; sparsely hairy. Cerci 2 segmented, hairy; length ca. 0.08–0.10 mm. Styli one jointed, tapering apically; length ca 0.08 mm.

Type-specimens All the type specimens as under "Material" are deposited in the National Reference Collection, Entomology Division, Forest Research Institute, Dehra Dun, as follows:

i. *Holotype*: One soldier from Phoolbagh, Haldwani, Uttarakhand.
ii. *Morphotype*: One pseudoworker from holotype lot and with the same data.
iii. *Paratypes and paramorphotypes*: Four paratype soldiers and *paramorphotype pseudoworkers*.

Type-Locality: India: Uttarakhand: Phoolbagh, Haldwani.

Distribution: Known only from the type locality.

Comparison: The soldiers of *Glyptotermes roonwali* n. sp. comes close to *Glyptotermes almorensis* Gardner but it differs from it as follows:

(i) Smaller species (total body-length 4.48–4.86 vs 4.8–5.7 mm; length of head to lateral base of mandibles 1.20–1.28 mm vs 143–173; head width 0.90–0.92 mm.
(ii) Anterior region of head-capusle yellowish to reddish brown or reddish brown in *Glyptotermes almorensis*.
(iii) Postmentum more than twice as wide anteriorly as posteriorly vs. less than twice as wide anteriorly as posteriorly in *Glyptotermes almorensis*.
(iv) Pronotum with posterior margin substraight with a weak depression in the middle vs posterior margin straight and without depression in the middle.
(v) Head-capsule in psuedoworkers yellowish white vs pale brown in *Glyptotermes almorensis* Gardner.

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Changes in eggshell sculpturing of *Oxya hyla hyla* (Orthoptera: Acrididae) during development

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ABSTRACT: Chorion sculpturing in *Oxya hyla hyla* (Orthoptera: Acrididae) was studied, using Scanning Electron Microscope, in three developmental stages, i.e. in follicle, in oviduct and just after laying. In follicle stage chorion was characterized by minute spicules with initiation of cap formation, oviduct stage was characterized by numerous grooves and cap formation, and after laying well pronounced fully formed cap and numerous grooves on the whole egg surface with hexagonal and pentagonal architecture were visible. Cap formation at the posterior pole of egg is reported for the first time. It is species specific and hence useful in systematics.

KEYWORDS: Acrididae, *Oxya hyla hyla*, chorion, SEM, eggshell, sculpturing

INTRODUCTION

Eggshell or chorion covers the ripe oocytes of insects with two distinct layers, the outer chorion and the inner vitelline membrane. It provides a strong and elastic mechanical protection to the developing embryo. Beament (1946) suggested that the morphology and architecture of chorion depended on the imprints of the follicular cells. The sculpturing of the outer part of the chorion has been proposed to be species specific and also has been used as taxonomical tool (Rosciszewska, 1991). Initial works on the eggshell of acridids was done by Hartley (1961) which revealed that the chorion had a meshwork of structures. Descriptions are available for the eggshell of *Melanoplus differentialis* (Slifer, 1937, 1949) and *Schisticerca gregaria* (Roonwal, 1954). Katiyar (1957) described the structure of the eggshell of some Indian Acrididae using light microscopic methods. Hinton and Service (1969) first pointed out that light microscopic photographs could give only a poor impression of the structure and the shape of the tubercles and ridges on the egg surface. Linley (1989) first published the SEM picture of eggshell of different species of *Aedes*. Ganguly *et al.* (2008) reported the egg surface sculpturing of two common Indian grasshoppers (Acrididae)

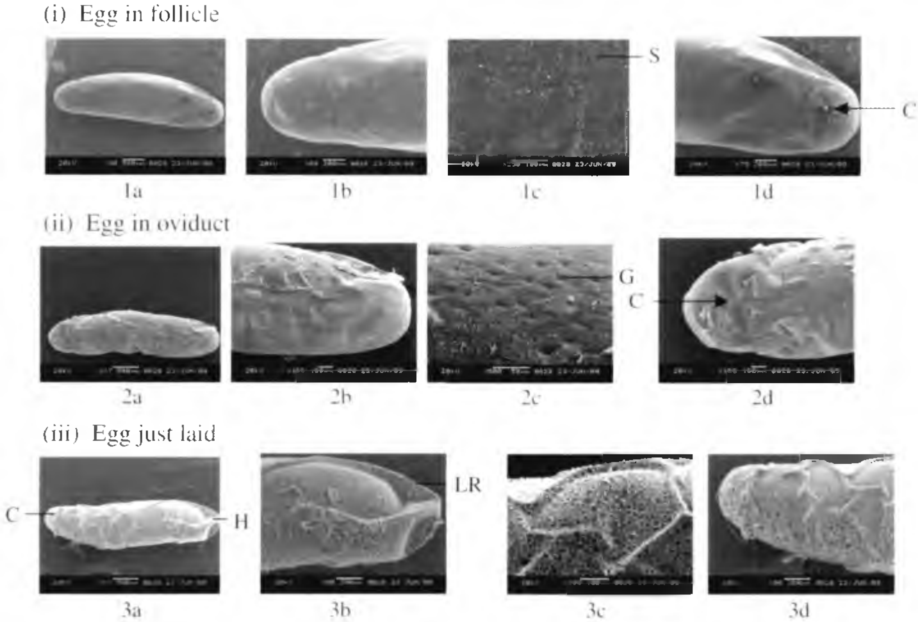
and discussed its taxonomic significance. But little information is available on the morphogenesis of the surface structure of chorion during its development and on that basis the present study was taken up.

MATERIALS AND METHODS

Different developmental stages of *O. hyla hyla* were collected from paddy fields in and around Agartala city. Ripe eggs were dissected out of the ovariole and the oviduct in Ringer's solution and cleaned in 100 mm Tris-HCl (pH 8.1). Eggs were collected while they were just laid, briefly washed in Tris-HCl buffer (50 mM, pH-8), fixed in 2% buffered cold gluteraldehyde (0.1M phosphate buffer, pH 7.2) for four hours and dehydrated in ice-cold graded acetone. The dehydrated eggs were dried by Tetra Methyl Silane for 5–10 min with two changes at 4°C and were brought to room temperature (25–26°C). Dried eggs were coated with gold and palladium in a JEOL Fine coat ion sputter JFC-1100, the coating was 35 nm thick and coated eggs were examined under a JEOL JSM-6360 Scanning Electron Microscope at different magnifications.

RESULTS AND DISCUSSION

SEM analysis revealed that the length of the whole egg in follicle (Fig. 1–3a) was 3.8 mm and width 1 mm. The anterior pole (Fig. 1–3b) contained some minor tubercles while the main surface of the egg (Fig. 1–3c) was comparatively smoother. In the posterior pole (Fig. 1–3d) the interesting feature was that the tubercles on the surface were more pronounced and some ridges were present which were perhaps initiation of a cap formation during later stages of development (arrow). The main body surface of this pre-oviposition chorion, under higher magnification showed very small spicule like structures evenly distributed over the whole surface. After release from the follicle the ripe eggs generally remained in the oviduct for sometime. Such eggs were also collected and subjected to SEM study (Fig. 2a). In such eggs anterior and posterior pole had minute tubercles (Figs. 2b, d). In the middle zone (Fig. 2c) many groove like structures were present. The posterior cap was fully formed in this stage (arrow). The cap was located 0.3 mm from the edge of the posterior pole. In freshly laid eggs subjected to SEM analysis, it was observed (Fig. 3a) that the anterior pole of the egg formed horn like structures and four ridges (Fig. 3b) from four margins which met together to form a torpedo like structure. Height of the ridges was about 0.1 mm and it was about 0.4 mm in length. The ridges from all four sides merged at the tip. The middle zone of the egg was divided by numerous pentagonal and hexagonal structures (Fig. 3c).These pentagons and hexagons were separated by ridges of different size. The length of the ridges varied from 100–278.57 μm. Length and width of the pentagons and hexagons were approx. 0.5 mm and 0.3 mm, respectively. The whole middle surface of these subdivisions were provided with numerous grooves and the size of the grooves were approx. 4.4 μm but in the posterior zone no pentagons and hexagons were present (Fig. 3d). On the contrary the surface became smooth and



FIGURES 1–3. Photomicrograph of the eggs of *Oxya hyla hyla* and Scanning Electron Micrograph of the anterior and posterior ends of the eggs in different growth stages: (i) Egg in follicle, (ii) Egg in oviduct, (iii) Egg just laid. a, Whole egg; b, anterior end; c, middle part; d, posterior end; S, Spicules; C, Cap; G, Groove; H, Horn like structures; LR, Lateral ridges.

a cap like structure was observed which covered the whole egg like a ring. It was present about 200 μm apart from the edge of the posterior zone. The width of the cap was 83.3 μm. Numerous grooves were present in this cap and some of those were comparatively larger in size than the grooves in the middle zone. Hartly (1961) reported patterning of acridid eggshells of six grasshopper species of England. Uvarov (1966) described six types of eggshell sculpturing, smooth surface, irregular tubercles, tubercles arranged in hexagons, hexagonal pentagonal or oval cells without tubercles, cells with corner tubercles and cells with corner and central tubercles. In the present study the pre-oviposition chorion showed less pronounced spicules evenly distributed throughout the whole surface while posterior cap was fully formed. Cap formation in the posterior pole has not been described in any insect so far but Yu and Crities (1985) has described the presence of such cap in the Nematoda egg. Reiger *et al.* (1980) described the cap formation in silkmoth egg. Thus from the present study it is clear that in case of Acridids cap formation in the posterior pole of the egg is a phenomena. The laid egg (Fig. 3a–d) showed bead like structures at the middle zone, and the posterior and anterior end had minute tubercles. Sculpturing of the surface was more pronounced in the laid egg, cap was fully formed. Such a developmental patterning and morphogenesis of surface structures of silk moth egg have been reported by Dey

et al. (2003). In freshly laid egg the middle zone of the egg was divided by pentagonal and hexagonal structures which were divided by ridges. Ganguly *et al.* (2008) have described such feature in the grasshopper, *Acrida exaltata* and *Heiroglyphus banian*. The present study is in conformity with their findings. The cap as reported in the present study was thick and numerous sculptures covered the cap. Van der Gulden and Van Aspert-Van Erp (1976) suggested that the hatching of eggs and permeability of the egg were function of the cap. The present study shows that the egg surface of *O. hyla hyla* undergoes a sequential change during its development and the final structure which is seen in the laid egg emerges late.

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Influence of feeding thrips infested mulberry (*Morus alba* L.) leaves on rearing performance of the silkworm *Bombyx mori* L.

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ABSTRACT: An experiment was conducted to find out the effect of feeding thrips infested mulberry leaves to the silkworm, *Bombyx mori* L. Thrips infestation adversely affected the economic characters of silkworm, viz. larval period, larval weight, effective rate of rearing, single cocoon weight, single shell weight and SR%. The decline was higher in the batches of silkworm fed with thrips infested leaves of mulberry variety MR2 compared to that of V1.

KEYWORDS: mulberry thrips, *Pseudodendrothrips mori*, silkworm rearing

Mulberry (*Morus alba* L.) is the sole food plant of the silkworm, *Bombyx mori* L. The quantity of leaves produced from the mulberry garden directly influence the silkworm rearing capacity whereas the quality of leaves play vital role on growth and development of silkworm and its economic parameters like effective rate of rearing, cocoon yield and silk ratio. The incidence of various pests and diseases in mulberry therefore causes both quantitative and qualitative losses which affect the silk productivity. Among the pests, the mulberry thrips *Pseudodendrothrips mori* Niwa (Thysanoptera: Thripidae) has become very destructive in many countries (Etebari and Bizhannia, 2006). In the present study an assessment was made on the impact of feeding thrips infested mulberry leaves on growth and development of silkworm and cocoon yield.

The study was conducted at Regional Sericultural Research Station, Salem, Tamil Nadu using two ruling mulberry varieties viz. V1 and MR2. The garden was maintained following recommended package of practices (Dandin *et al.*, 2003) with two sets of conditions i.e. protected and unprotected. In unprotected plots no plant protection measures were taken up thereby allowing the natural infestation of thrips

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TABLE 1. Effect of feeding thrips infested mulberry leaves on rearing performance of ***B. mori*** (PM X CSR2)

Type of leaves fed	Larval duration (d)	Larval weight (g)	ERR%	Defective cocoon (%)	SCW (g)	SCW (g)	Silk ratio (%)
Variety V1							
Thrips infested	26:08	28.21 ± 1.51*	83.00 ± 2.75*	13.90 ± 2.05*	1.252 ± 0.15*	0.228 ± 0.022*	16.44 ± 0.39*
Control	24:03	34.55 ± 1.02	95.20 ± 3.03	4.90 ± 1.52	1.447 ± 0.14	0.260 ± 0.040	17.98 ± 0.54
Variety MR2							
Thrips infested	27:12	25.14 ± 1.03*	77.20 ± 3.01*	19.00 ± 2.44*	1.197 ± 0.08*	0.166 ± 0.016*	13.89 ± 0.45*
Control	24:03	33.15 ± 0.88	95.00 ± 1.33	4.80 ± 1.75	1.419 ± 0.10	0.245 ± 0.018	17.30 ± 0.63

Values are mean ±SD; *Significant at $P < 0.05$.
ERR, Effective rate of rearing; SCW, Single cocoon weight; SSW, Single shell weight; SRI, Silk ratio.

and in the protected plots 0.2% dimethoate was applied twice at weekly intervals (Rajadurai and Thiagarajan, 2003). The popular multi X bivoltine silkworm hybrid (PM X CSR2) was mass reared up to second stage and then the larvae were divided into two lots, each having 1000 larvae replicated 10 times @ 100 larvae/replication. First lot was fed with healthy leaves (thrips free) obtained from the protected plots while another was fed with infested leaves, till worms started spinning the cocoons. Leaves from both mulberry varieties, MR2 and V1 were subjected to same treatment separately. Data on the economic parameters like larval period, larval weight, effective rate of rearing, single cocoon weight, single shell weight, and SR% were recorded.

The larvae fed with the thrips infested leaves from both V1 and MR2 varieties showed significantly longer duration and reduction in larval weight compared to the control larvae of respective varieties (Table 1). Effective rate of rearing %, defective cocoon %, single cocoon weight, single shell weight and silk ratio in the batches of larvae fed with thrips infested V1 and MR2 leaf were significantly reduced compared to the corresponding values in the control batches. For all parameters more adverse effect was observed in the lot fed with MR2 leaf compared to V1 leaf.

Most of the mulberry varieties are susceptible to thrips attack (Naik, 1997) but some host preference exists. There is variation in the number of thrips on different mulberry varieties (Xi and Zhu, 1991). Infestation of thrips is reported to be more prominent in MR2 (Rajadurai and Thiagarajan, 2003) than in V1 which explains this difference in rearing performance. Apparently this depletion of moisture and nutritional values was more in MR2. Similar results in Kenmochi mulberry variety was recorded as compared to Ichenoise variety in Iran (Etebari and Bizhannia, 2006). They recorded proportionate reduction of chemical properties with the intensity of thrips infestation in mulberry leaves and its significant adverse effect on cocoon parameters. Outbreak of mulberry thrips was reported in many parts of the country and especially in summer months it brings down the cocoon productivity (Venugopala and Krishnaswami, 1983; (Bhattacharya *et al.*, 1993; Das *et al.*, 1994; Rajadurai and Thiagarajan, 2003)). The present study suggests that planning suitable IPM for this pest and avoiding cultivation of susceptible mulberry varieties in thrips prone zone can avoid economic loss to the sericulture farmers. Study on the host preference of *P. mori* in different parts of the country will be very useful to develop a suitable package of IPM.

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Development of *Riptortus pedestris* F. (Hemiptera: Alydidae) on coffee senna weed, *Cassia occidentalis* L. in cowpea ecosystem

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ABSTRACT: Coffee senna weed, *Cassia occidentalis* L. prevalent in cowpea ecosystem supported the development of *Riptortus pedestris* F. a major pest of the crop in Kerala. The bug completed its development on *C. occidentalis*, vegetable cowpea (*Vigna unguiculata* ssp. *sesquipedalis* (L.) Verdcourt and in grain cowpea (*Vigna unguiculata* (L.) Walp in 24, 21.4 and 24.24 days, respectively. Though the longevity and the fecundity of the pest grown on the weed were comparatively lower, they were sufficiently high to cause population build up in the field and hence removal of the weed is suggested as a desired step in the management of the pest.

KEYWORDS: *Riptortus pedestris*, *Cassia occidentalis*, *Vigna unguiculata* ssp. *sesquipedalis*, *Vigna unguiculata*

Riptortus pedestris F. is a commonly occurring pod bug of legumes in India. Tender pods of affected plants failed to develop fully and older pods were rendered unfit for culinary or seed purpose (Visalakshi *et al*., 1976). Coffee senna weed, *Cassia occidentalis* L. was found to harbour nymphs and adults of this pod bug under field situations in Kerala. As knowledge on the biology of a pest in crop plants and weeds would be helpful in chalking out management measures, attempts were made to study the development of the bug in the weed plant *C. occidentalis* in comparison with its development on two of its important host plants *viz*., *Vigna unguiculata* ssp. *sesquipedalis*, (L.) variety Sharika and grain cowpea *Vigna unguiculata* (L.) Walp variety Pusa komal.

Excised fresh pods confined in glass chimneys were used for rearing the bugs. The experiment was conducted in completely randomized design with ten replications.

C. occidentalis could support the survival and development of *R. pedestris* (Table 1). It took 24 days to complete development on the weed and 21.4 and 24.24 days on

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TABLE 1. Biology of *Riptortus pedestris* on different hosts in cowpea fields in Kerala

Stage	Duration (days) on			
	Coffee senna weed	Vegetable cowpea var. Sharika	Grain cowpea Var. Pusa Komal	CD (0.05) for comparing hosts
Egg	**8.15**	7.88	7.55	0.244
Instar I nymph	**1.69**	1.58	2.42	0.072
Instar II	**3.03**	2.77	3.38	0.072
Instar III	**3.13**	2.41	2.92	0.178
Instar IV	**2.28**	2.68	3.14	0.052
Instar V	5.72	4.08	4.83	0.094
Total nymphal period	15.84	13.52	16.69	0.245
Total life cycle	24.00	21.40	24.24	0.370
Adult male	36.40	53.60	54.30	3.615
Adult female	44.00	61.40	59.70	4.681
Oviposition period	6.10	9.20	8.70	1.231
Fecundity (No)	27.30	94.40	76.90	7.849

vegetable cowpea and grain cowpea. The total nymphal period and total life cycle were shorter (13.52 and 21.40 days, respectively) on vegetable cowpea. The longest oviposition period (9.20 days) and the highest fecundity (94.40) were also observed on this host. Hence vegetable cowpea is the most suitable host of *R. pedestris*. Khaemba (1984) opined that purple and dark green poded cultivars of cowpea were more resistant to pod bugs than those with light green pods. The light green shade and succulent nature of vegetable cowpea pods might have made it a superior host of *R. pedestris*. Grain cowpea and coffee senna weed had darker green colour. Gerard (1984) stated that pubescence is an effective defence against pests attacking cowpea cultivars. The glabrous nature of vegetable cowpea might have been yet another favourable factor for *R. pedestris*. In coffee senna weed, the nymphs completed their development in significantly shorter period (15.84 d) compared to grain cowpea (16.69 d). However, the longevity of the adult male and female bugs, oviposition period and fecundity were higher in vegetable cowpea and grain cowpea compared to the weed. Since coffee senna weed which supports the development of *R. pedestris* is plentiful in fields it can act as a reservoir and help to carry the population into the next cropping season. So the removal of the weed from the vicinity of cowpea fields would be a desirable practice in regulating the population of *R. pedestris*.

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Consumption and utilization of different food plants by *Chrotogonus trachypterus* Blanchard (Orthoptera: Acrididae)

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ABSTRACT: A laboratory study was conducted on consumption and utilization of different food plants by fifth instar nymphs of *Chrotogonus trachypterus* Blanchard, a polyphagous pest from semi arid zone of Rajasthan. Among ten plant species belonging to five families tested, *Spinacea oleracea* (Amaranthaceae), *Lycopersicon esculentum* (Solanaceae) and *Brassica oleracea* var. *botrytis* (Brassicaceae) were the most suitable on the basis of growth rate and were at par. Other host plants in decreasing order of food value were *Cicer arietinum* (Fabaceae), *Pennisetum typhoideum*, *Triticum aestivum*, *Cynodon dactylon* (Poaceae) and *Brassica oleracea* var. *capitata* (Brassicaceae). *Arachis hypogea* (Fabaceae) and *Solanum melongena* (Solanaceae) were least suitable host plants. Efficiency of conversion of digested food (ECD) and efficiency of conversion of ingested food (ECI) into body matter was significantly associated with the growth rate (GR) of nymphs. Growth also increased with higher consumption index (CI). Approximate digestibility (AD) did not show a significant impact on growth of the insect.

KEYWORDS: *Chrotogonus trachypterus*, growth rate, consumption and utilization indices

Surface grasshopper, *Chrotogonus trachypterus* Blanchard is a widely distributed polyphagous insect causing severe damage to a wide variety of plants in seedling stage (Grewal and Atwal, 1968). A polyphagous pest may cause varying damage to host plants. Information on consumption and utilization of food by insects is of vital importance in physiology of nutrition. Mehrotra *et al.* (1972) and Sanjayan and Murugan (1987) studied consumption, digestion and utilization by locusts and grasshoppers. Effect of certain food plants on the growth, development and food preference of *Atractomorpha crenulata* Fabricius was reported by Singh and Srivastava (1990) and Nath *et al.* (2009). Bernays and Chapman (1973) recorded that food quantity affected the rate of development in insects. A number of wild

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plants have a detrimental effect on insect life. Such plants have great promise in crop rotation. Survivability of insects also depends upon the type of food (Bernays *et al.*, 1975). A clear picture of comparative nutrition of insects did not emerge until quantitative studies were emphasized (Prem Kumar *et al.*, 1977). Various studies on effect of food plants on fecundity, fertility, longevity and seasonal abundance have been conducted on *Chrotogonus trachypterus* (Mittal *et al.*, 1978; Chandra and Mittal, 1984). However, there is no detailed study on the effect of different host plants on consumption and utilization of food of this insect. The above aspects were hence studied on fifth instar female nymphs of *C. trachypterus*.

Adults of *C. trachypterus* were reared on cabbage in the laboratory at 35 ± 1 °C and 60 ± 5% RH. Newly moulted fifth instar nymphs were obtained from the culture and released in glass jars individually containing different food plants of known weight. Each treatment was replicated five times. Before providing food the nymphs were weighed. Every day the weights of nymphs, unconsumed food, and faecal matter were recorded till the nymphs became adult. Fresh leaves of experimental food plants were kept without insects in similar jars. Weight of these leaves was also recorded daily to calculate the moisture loss in treatment. Different indices of consumption and utilization of food were calculated following the method of Waldbauer (1968) and Singh and Sehgal (1993).

Insects reared on *Spinacea oleracea* (Amaranthaceae), *Lycopersicon esculentum* (Solanaceae) and *Brassica oleracea* var. *botrytis* (Brassicaceae) showed higher growth rate (0.040, 0.038 and 0.037, respectively) and were on par (Table 1). These food plants were followed by *Cicer arietinum* (Fabaceae) (0.026), *Pennisetum typhoideum* (0.016), *Triticum aestivum* (0.014), *Cynodon dactylon* (Poaceae) (0.012) and *Brassica oleracea* var. *capitata* (Brassicaceae) (0.012). *Solanum melongena* (Solanaceae) and *Arachis hypogea* (Fabaceae) (0.006) had minimum growth rate and may be regarded as least nutritious for development of this insect.

Efficiency of conversion of ingested food (ECI) and efficiency of conversion of digested food (ECD) into body matter were higher on more preferred food i.e. *S. oleracea*, *L. esculentum* and *B. oleracea* var. *botrytis* and significantly correlated with growth rate. Consumption increased with increase in nutritional value of food. Consumption index (CI) was also significantly related with growth. Approximate digestibility (AD) did not play a decisive role in the relationship between digestion and growth. It is likely that the qualitative factors are more important. Similar observations had been made by Fraenkel and Soo Hoo (1966) that growth was directly related to digestion or assimilation of food but ingestion of plant did not ensure growth. Low digestibility of plants may result in most of the ingested material being voided in the faeces rather than being assimilated. Waldbauer (1968) observed that the rate of feeding in insect was limited by the response to the bulk water content and other physical properties of whole fresh food. In the present study lower ECD was noticed in nutritionally deficient plants like *S. melongena* while *S. oleracea* showed a greater ECD. The ECI of insect fed on these plants followed ECD pattern and these results are similar to the findings of Bailey and Mukerji (1976) who revealed that a nutritional

TABLE 1. Consumption and utilization indices of different food plants by fifth instar nymphs of *Chrotogonus trachypterus*

Food plant	CI	GR	AD	ECI	ECD
Brassica oleracea var. *capitata* (Cabbage)	0.053	0.012	90.62	23.65	26.09
Brassica oleracea var. *botrytis* (Cauliflower)	0.081	0.037	88.16	46.95	53.24
Lycopersicon esculentum (Tomato)	0.101	0.038	84.29	38	45.1
Solanum melongena (Brinjal)	0.027	0.006	91.69	24.52	26.66
Spinacea oleracea (Spinach)	0.025	0.041	87.58	73.86	84.34
Triticum aestivum (Wheat)	0.043	0.014	94.32	33.24	35.24
Pennisetum typhoideum (Bajara)	0.029	0.016	82.68	56.31	68.11
Cicer arietinum (Gram)	0.094	0.026	95.43	28.38	29.73
Arachis hypogea (Groundnut)	0.024	0.006	94.63	30.76	32.52
Cynodon dactylon (Doob grass)	0.039	0.012	91.82	28.59	31.17
Pearson Correlation Coefficient (r)	0.5758**		0.4851 ns	0.6393**	0.63568**

CI, Consumption index; GR, Growth rate; AD, approximate digestibility, ECI, Efficiency of conversion of ingested food to body substances; ECD, Efficiency of conversion of digested food to body substance.
** Highly significant
ns Non significant

deficiency in the plant could cause the digested portion of the food to be poorly utilized, resulting in a lower ECD and ECI. These results are also in consonance with the the findings of Singh and Sehgal (1993) who studied the consumption and utilization of different food plants by larvae of *Spilosoma obliqua* Walker. Castor was rated as the best food followed by soybean and cabbage in decreasing order in view of their high growth rate, ECI and ECD values inspite of lower consumption index and approximate digestibility (AD).

There was significant correlation between consumption, utilization of food and growth rate of insects. The overall results revealed that *Spinacea oleracea, Lycopersicon esculentum* and *Brassica oleracea* var. *botrytis* are better food plants for *C. trachypterus, and Arachis hypogea* and *Solanum melongena* were least suitable.

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Thysanoptera fauna of the oak fields of Manipur and Nagaland, north-east India

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ABSTRACT: In a survey in the oak (*Quercus* sp.) growing regions of Manipur and Nagaland, NE India from 2000 to 2008, 30 species of thrips belonging to 24 genera, comprising 12 phytophagous and 18 mycophagous (litter dwelling) forms were collected. Three species belonged to the family Thripidae (suborder Terebrantia) and 27 to the family Phlaeothripidae (suborder Tubulifera). Among the 30 species, 24 are endemic to India of which nine are endemic to the north-east region.

KEYWORDS: thrips, Thysanoptera, oak, north-east India

A vast area between the latitude 24°–34° N and longitude 73° 5'–95° E, spreading across the Sub Himalayan region is on Oak belt (Jolly, 1967). The States of Manipur and Nagaland in this sector have about 60,000 ha of natural growth of oak, belonging to the genus *Quercus*. It is an economically important plant not only for timber and fire wood but also as an essential host for the silkworm of the genus, *Antheraea* (Negi and Naithani, 1995). Oak plants harbour a number of phytophagous insects (Feeny, 1970) and thrips are important among them (Ananthakrishnan and Sen, 1980; Varatharajan *et al.*, 1995). In the present study, a survey was made for thrips infesting different species of oak in this region.

Thrips were collected by yellow pan water trap method, delayed collection, and counting technique (Singh *et al.*, 1996). Tulgren funnel method was also adopted to collect litter dwelling mycophagous thrips (Ananthakrishnan, 1984). Collections were made during spring, summer and autumn seasons over the years 2000 to 2008. Specimens were identified with the help of standard taxonomic keys and reference slides (Ananthakrishnan and Sen, 1980; Varatharajan, 2005).

Eighteen mycophagous and 12 foliage inhabiting thrips belonging to 24 genera were recorded (Table 1). Among them, only three species belong to the suborder Terebrantia and the rest were Tubuliferans. Both the States of Manipur and Nagaland have different

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TABLE 1. Thrips collected from the oak fields of Manipur and Nagaland

Species	Habitat	Place of collection
Suborder Terebrantia		
Family Thripidae		
Parabaliothrips coluckus (Kudo)	Leaf	Kohima (1400 m), Nagaland; Moreh (1000 m), Manipur
Selenothrips rubrocinctus (Giard)	Leaf	Mantripukhri (750 m), Manipur; Kikruma (1100 m), Nagaland
Hydatothrips ananthakrishnani Bhatti[a]	Leaf	Canchipur (750 m), Manipur
Suborder Tubulifera		
Family Phlaeothripidae		
Adraneothrips disjunctus Ananthakrishnan[a,c]	Litter	Joyland, Ukhrul (1350m), Manipur
Allothrips pillichellus bicolor Ananthakrishnan[a,c]	Litter	Ukhrul (1400 m), Manipur
Apelaunothrips consimilis (Ananthakrishnan)[a,c]	Litter	Litan, Ukhrul (1500 m), Manipur
Araeothrips vamana Muraleedharan[b]	Leaf	Wokha, (1310 m), Nagaland, Moreh, (1000 m), Manipur
Bactrothrips idolomorphus Karny	Litter	Ukhrul (1350 m), Manipur
Bactrothrips luteus Ananthakrishnan[a,c]	Litter	Ukhrul (1350 m), Manipur
Bradythrips hesperus Hood & Williams[a,c]	Litter	Mantripukhri (750 m), Manipur
Coxothrips tarai (Stannard)[a]	Litter	Joyland (1350 m), Manipur
Dexiothrips madrasensis (Ananthakrishnan)[a,c]	Litter	Ukhrul (1350 m), Manipur
Ecacanthothrips tibialis (Ashmead)	Dry twigs	Mantripukhri (750 m), Manipur
Elaphrothrips insignis Ananthakrishnan[a,c]	Dry twigs	Wokha (1310 m), Nagaland
Elaphrothrips spiniceps Bagnall	Dry twigs	Khangkhui (1350 m), Manipur
Hoplothrips orientalis (Ananthakrishnan)[a,c]	Litter	Mokokchung (1350 m), Nagaland
Holurothrips manipurensis Varatharajan & Chochong[b]	Litter	Litan, Ukhrul (1500 m), Manipur
Leeuwenia ananthakrishnani Varatharajan & Sen[b]	Leaf	Langol (750 m), Manipur; Kikruma (1400 m), Nagaland
Leeuwenia maculans Priesner & Seshadri[a,c]	Leaf	Mokokchung (1350 m), Nagaland, Langol (750 m), Manipur
Liothrips himalayanus Ananthakrishnan & Jagadish[b]	Leaf	Langol (750 m), Manipur
Mecynothrips simplex Bagnall	Leaf	Hundung (1350 m) Manipur
Meiothrips menoni Ananthakrishnan[a,c]	Leaf	Tadubi (1350 m), Manipur
Meiothrips nepalensis Kudo & Ananthakrishnan[b]	Leaf	Tamenglong (1350 m), Manipur
Mesothrips bombicinus Nilamani & Prasad[b]	Leaf	Mantripukhri (750 m), Manipur
Mesothrips extensivus Ananthakrishnan & Jagadish[a,c]	Leaf	Moreh (1000 m), Manipur

TABLE 1. (Contd...)

Species	Habitat	Place of collection
Mesothrips latus Muraleedharan & Sen[b]	Leaf	Moreh (1000 m), Manipur
Ocnothrips indicus Ananthakrishnan[a,c]	Leaf	Moreh (1000 m), Manipur
Praepodothrips priesneri Ananthakrishnan[a,c]	Leaf	Gwaltabi, Ukhrul (1400 m), Manipur
Stigmothrips okajimai Muraleedharan & Sen[b]	Litter	Mantripukhri (750 m), Manipur
Tylothrips indicus Sen & Muraleedharan[b]	Litter	Joyland (1350 m), Manipur

Leaf refers to leaf of *Quercus serrata* and litter refers to mixed leaf litter of *Quercus* spp.
[a]Species endemic to India; [b]Species endemic to north-east India; [c]Species first discovered from south India

species of *Quercus* trees viz *Q. serrata* Thunb., *Q. semiserrata* Roxb., *Q. dealbata* Hook. F & Thomas, *Q. griffithi* Thomas and *Lithocarpus dealbata* Hook. F & Thomas. *Q. serrata* harboured the majority of the leaf feeders, while the leaf litter of all the *Quercus* species yielded the mycophagous thrips. The survey was undertaken in the hilly terrains ranging from 750 m to 1500 m MSL. The diversity of thrips species was greater in the high altitude areas (>1300 m). This is evident especially with litter dwellers. Similar observation was also recorded by Ananthakrishnan (1984) with respect to the mycophagous forms in the hilly terrains of the Western Ghats region. On the other hand, the diversity of phytophagous species was appreciably more between the altitudes of 750 and 1000 m MSL (Table 1). Such differences could be attributed to variation in the climatic condition besides certain agronomic practices like pruning that leads to sprouting of more tender leaves at the low altitude. The burial of leaf litter and pruned twigs might be the reason for reduction in density and diversity of mycophagous thrips at the low altitude.

Among the 30 thysanopterans, species such as *Selenothrips rubrocinctus* (Giard), *Leeuwenia ananthakrishnani* Varatharajan & Sen and *Coxothrips (=Ananthakrishnaniella) tarai* Stannard (1970) are very specific to *Quercus* sp. The rest were collected from other plant species besides oak (Varatharajan, 2005). Stannard (1970) collected *C. tarai* only from the oak growing regions of Tarai (Uttaranchal State) (Ananthakrishnan and Sen, 1980). Besides Tarai region, this endemic species has not been recorded from any other State and the present record is the first from Manipur and Nagaland. Such distribution indirectly highlights the oak belt connectivity from north to north-east India through the Sub Himalayan region.

Out of the 30 species, 24 are endemic to India (Table 1). Of these, 13 species were described from Southern India — two species (C. *tarai* and *Hydatothrips ananthakrishnani* Bhatti) from Sub Himalayan sectors of northern India (Ananthakrishnan and Sen, 1980) and nine species from north-east India (Sen *et al.*, 1988). It appears that the Northeast is a mixed bag comprising elements from North and South India in addition to elements of its own. The north-east region's proximity to other countries of SE Asia

enables it to share certain genera of thrips like *Mesothrips* and *Leeuwenia* which are of Indo-Malayan origin.

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Population dynamics of round headed stem borer, *Aeolesthes holosericea* Fabr. (Coleoptera: Cerambycidae) in arjun ecosystem of Andhra Pradesh and its correlation with abiotic factors

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ABSTRACT: The influence of weather factors in different periods of 2007–09 on population of round headed stem borer, *Aeolesthes holosericea* on *Terminalia arjuna* plantations revealed that highly significant variations existed in the different months for density, infestation and intensity parameters whereas variations recorded during different weeks and years were not significant. Correlation studies confirmed that sunshine hours evinced highly significant positive association with borer activity. Minimum temperature and evening R.H. exhibited significant negative correlation with borer population.

KEYWORDS: *Aeolesthes holosericea*, *Terminalia arjuna*, population density

Arjun (*Terminalia arjuna* Bedd), Asan (*Terminalia tomentosa* W&A) and Sal (*Shorea robusta* Roxb.) are multipurpose trees and primary host plants of tropical tasar silkworm, *Antheraea mylitta* Drury (Lepidoptera: Saturniidae). Among the key pests of tasar silkworm host flora, stem borer complex comprising the buprestids, *Sphenoptera cupriventris, S. indica, S. koenbieresis* and *Psiloptera fastuosa*, and the cerambycid, *Aeolesthes holosericea* are predominant on *T. arjuna* and *T. tomentosa* in Jharkhand and Andhra Pradesh (Rahman and Khan, 1942; Singh *et al.*, 1987; Reddy *et al.*, 1998; Kar and Mishra, 2000). *Sphenoptera dadkhani* and *S. laferti* usually infest peach plantation of Punjab (Chaudhary *et al.*, 1996). A devastating cerambycid stem borer, *Hoplocerambyx spinicornis* infesting Sal occur in epidemic form during November–January leading to degeneration of forests in Madhya Pradesh (Tiwari *et al.*, 1998).

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TABLE 1. Population dynamics of *A. holosericea* on *T. arjuna*

Month of observation	Density	% infestation	Intensity
August	0.14	6.47	1.98
September	0.23	13.04	1.80
October	0.82	26.88	2.98
November	2.20	35.79	6.25
December	3.39	53.56	6.31
January	4.37	58.57	7.21
February	0.88	26.65	2.62
CD	0.92	10.82	1.59

Pooled data for 2007–08 and 2008–09

Borers are considered to be a limiting factor in maintenance of economic plantations of Tasar host flora, inflicting 25–30% plant mortality, with high infestation causing up to 65% mortality in various parts of the country (Sinha *et al.*, 2000). According to Jaya Prakash *et al.* (2007) 0.15 lakh ha out of total 13.02 lakh ha of tasar silkworm host flora are under effective utilization for tasar cocoon production and severe attack of the hosts by borers is a regular phenomenon in Andhra Pradesh. The present study aimed to gather information on population build up of *A. holosericea* under varying meteorological conditions.

Population dynamics of *A. holosericea* F., was assessed in *Terminalia arjuna* forestry ecosystem of Regional Tasar Research Station, Warangal, Andhra Pradesh (latitude 17°-19′ and 18°-36′ North, longitude 78°-49′ and 80°-43′ East, altitude 870–1700 ft) in semi-arid type of climate, temperature ranging from 20 to 40° C, average relative humidity of 50% and rainfall of 650 to 850 mm. Presence of irregular, shallow galleries and holes in the bark of stem and crown portions of the trees is the characteristic sign of infestation. The galleries are filled with dark brown frass and excreta tightly packed in a long web like structure. Twenty plants were chosen at random from each of 10 plots demarcated for this study, thus making altogether 200 samples for observation. Population counts were done at weekly interval during the months of August to February 2007–08 and 2008–09. Borer population was assessed by counting grubs in the upper layer of the bark located under the webbed galleries, with the help of spoke and secateure. This operation was followed by plugging of holes and galleries of the dissected portion with cotton pads steeped in monocrotophos (0.02%) and pasting with clayey soil drenched in mobile oil. The number of grubs divided by total number of plants sampled and number of infested plants were treated as density and intensity of attack, respectively. The percentage of infested plants out of the total number sampled was treated as percent infestation.

The data were subjected to analysis of variance. Variations in the data among different weeks in various months and between the years 2007–08 and 2008–09 did not show statistical significance. Hence the mean values for different months alone are shown in Table 1. Relationship between abiotic factors and borer population

TABLE 2. Correlation between abiotic factors and incidence of *A. holosericea*

Weather parameter	Borer activity		
	Density	% Infestation	Intensity
Max. temperature	−0.2064	−0.2690	−0.2650
Min. temperature	−0.8143**	−0.8700**	−0.8690**
Morning relative humidity	−0.3867	−0.4412	−0.4386
Evening relative humidity	−0.5521*	−0.6239*	−0.6206*
Sunshine	0.3963**	0.5731**	0.5613**
Rainfall	−0.5797	−0.7039	−0.6968

Pooled data for 2007–08 and 2008–09; *Significant at 5% level; **Significant at 1% level.

(density, infestation and intensity) was also studied by correlation analysis and data are presented in Table 2.

The lowest population, based on density, percentage infestation and intensity, was found in January (means being 5.43, 6.47% and 1.98 respectively) and it increased gradually every month. The parameters remained on par with January levels upto the end of October. From November there was conspicuous increase in the infestation, the maximum recorded being in the second week of January. In February, the density, percentage and intensity of infestation, came on par with corresponding figures of August of the previous year. Thus the infestation was significantly higher during the months of November, December and January compared to the remaining periods of the year. Such variations in the monthly occurrence of *A. holosericea* was reported earlier also (Singh *et al.*, 1987; Kar and Mishra, 2000)

The correlation of borer activity with weather parameters is shown in Table 2. Minimum temperature and evening R.H. were negatively and significantly associated with the grub population. Maximum temperature, morning RH and rainfall also showed negative correlation with the pest incidence but the correlation was not statistically significant. Daily sunshine hours had a highly significant positive correlation with the borer population. The present findings are in agreement with those of Singh *et al.* (1992) and Reddy *et al.* (1998) who observed peak incidence of *P. fastuosa* in Jharkhand and *S. cupriventris* in Andhra Pradesh during cooler months of the year and exhibited significant correlation with temperature, RH and rainfall. Chaudhary *et al.* (1996) and Lakra *et al.* (1980) reported that *S. dadkhani* and *S. laferti* populations showed positive correlation with temperature in peach orchards of Punjab. Kar and Mishra (2000) reported positive phototropism in *A. holosericea* grubs mostly found in stem or shoot which receive high sunlight. These findings highlight the desirability of adopting suitable control measures against the beetles during October to January.

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